جامعة عين شمس
كلية البنات للآداب و العلوم و التربية

Chemistry Department

Applications of Functionalized Natural and Synthetic Macromolecules

Prestel by

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2022-2023

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• Introduction

In this work, we will discuss the applications of functionalized natural and synthetic macromolecules so we will start with the definition of biodegradable polymers because chitosan is one of its types and Chitosan is a product of the deacetylation of chitin, chitosan contains active functional groups that are liable to chemical reactions; thus, chitosan derivatives can be obtained through the chemical modification of chitosan. The modification of chitosan has been an important aspect of chitosan research, showing a better solubility, pH-sensitive targeting, an increased number of delivery systems, etc. Chitosan has been conjugated with polyphenols to overcome the limitations of both chitosan and polyphenol, along with increasing the potential synergistic effects of their combination for therapeutic applications. And now we found that chitosan and its derivatives have been gaining more attention due to their high integration into various biomedical applications. Herein, a new chitosan derivative was prepared by linking the chitosan (Cs) with a novel heterocyclic compound,benzoimidazolyl-thiadiazole (BzimTD) to form Cs-BzimTD and two new polymers designated as Cs-EATT and Cs-BATT have been synthesized via linking the chitosan with The synthesized 1,3,4-thiadiazole compounds .and we will take about natural macromolecules for example the guar gum and gum arabic finally we will explain the electrical conductivity of oxadiazole and triazole polymer content.

• Discussion

1. Biodegradable Polymers: Classifications and Challenges: Depending on the source of origin, biodegradable polymers can be classified as either derived naturally through fermentation or by extracted biomass based precursor through polymerization **[1–2].** Various categories of biodegradable polymers derived from agricultural sources such as polysaccharides or protein based polymers and bio polyesters which are usually extracted from micro-organisms through biotechnological routes or derived from petroleum derivatives.

The first category of biopolymers are those which are derived directly from bio-sources and consist of polysaccharides, lipids and proteins. Polysaccharides that include cellulose, chitosan, gum, starch, pectin, etc., are the most abundantly available and naturally derived biopolymers. These are generally extracted from renewable lingo cellulose biomass, sea creatures and agricultural resources **[3, 4].**

It is noteworthy to mention that naturally occur-ring polymers such as cellulose, chitosan and silk have superior mechanical properties but show poor film forming ability and due to their hydrophilic nature they also show lower stability under ambient conditions **[5]**

2. Chitosan Based Composites: Chemical Modification

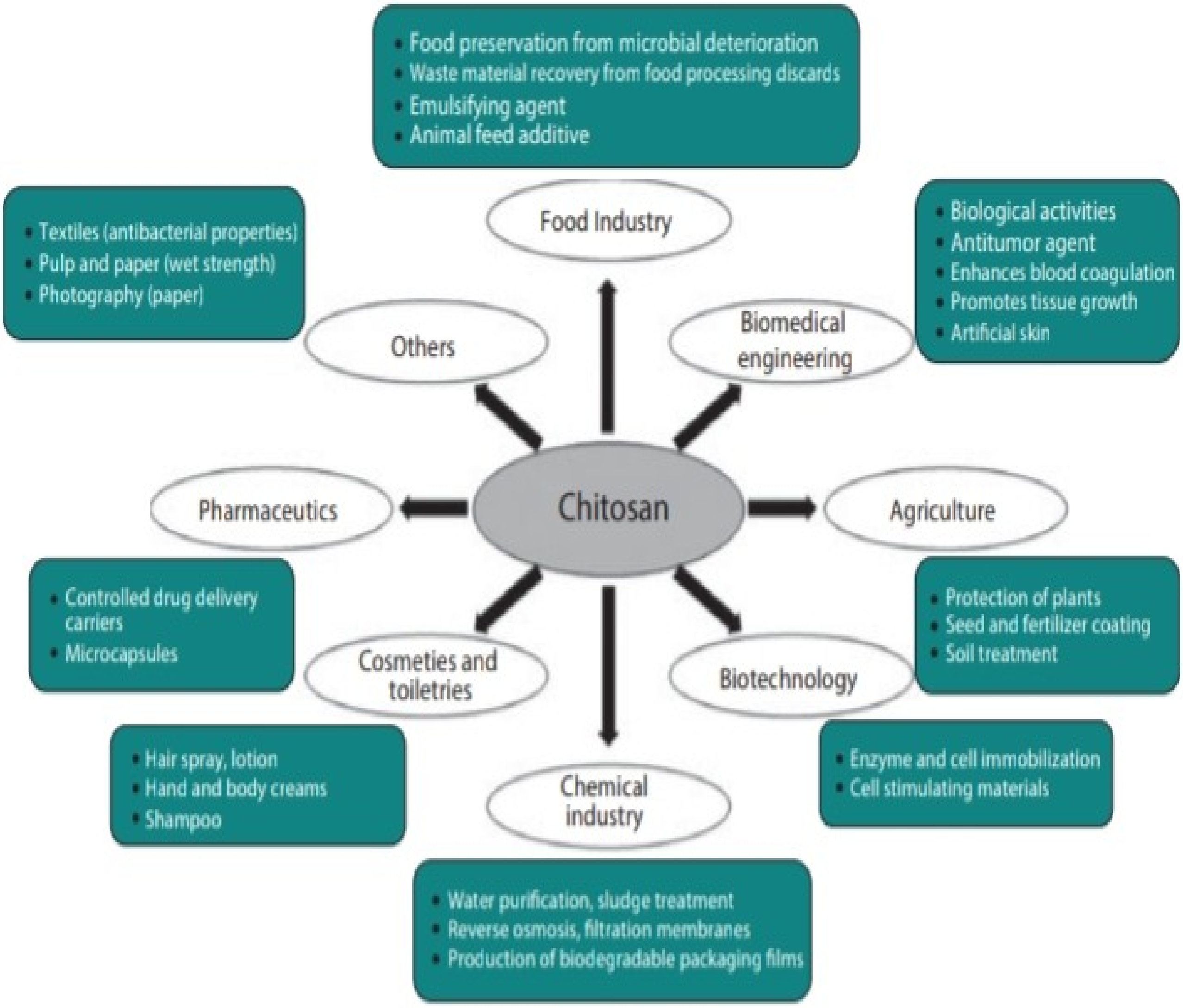
Properties Evaluation and Applications

Chitosan is a derivative of chitin and is produced by a simple step of de acetylation or de polymerization under the influence of strong alkaline conditions (concentrated sodium hydroxide) or enzymatic hydrolysis with the help of chitin deacetylase**.** **[6]** Chitosan shows enormous possibilities of physical and chemical modifications via ionic interactions and grafting due to the presence of -OH and -NH2 groups, which form a range of chitosan derivatives. **[7].**

In recent years, chitin and chitosan have been produced at commercial scale in many countries including India, Poland, Japan, Norway, Australia and USA. Both, chitin and chitosan are employed in countless applications e.g. as adsorbents for the removal of dyes **[8]**and metal ions

[9] in waste water treatment, fat binder in food industry **[10],** thin membranes in filtration processes **[11],** edible layer in packaging **[12],** coating material for fertilizer and seeds in agriculture **[13],** food additive and preservative **[14],** controlled release of agrochemicals **[15]**, Lotions and body creams in cosmetics **[16],** adhesive paper **[17]** and surface treatment **[18]** in pulp and paper industry, wound healing **[19],** tissue engineering **[20],** gene delivery **[21],** vehicle for drug delivery **[22]**

As shown in **Figure 1.**



Food preservation from microbial deterioration
Waste material recovery from food processing discards
Emulsifying agent
Animal feed additive
Textiles (antibacterial properties)
Pulp and paper (wet strength)
Photography (paper)
Food Industry
Biological activities
Antitumor agent
Enhances blood coagulation
Promotes tissue growth
Artificial skin
Others
Biomedical engineering
Pharmaceutics
Chitosan
Agriculture
Controlled drug delivery carriers
Microcapsules
Protection of plants
Seed and fertilizer coating
Soil treatment
Cosmeties and toiletries
Biotechnology
Hair spray, lotion
Hand and body creams
Shampoo
Enzyme and cell immobilization
Cell stimulating materials
Chemical industry
Water purification, sludge treatment
Reverse osmosis, filtration membranes
Production of biodegradable packaging films

Figure 1. Potential applications of chitosan and its derivatives in various sectors.

Chitosan is widely used in packaging applications due to its biodegradability, non-toxicity and film forming ability. This property was utilized by Khan et al., who fabricated biodegradable films using chitosan as matrix and nanocrystalline cellulose (NCC) as filler with 1-10 wt. %

loading, using the solution casting method **[23].**

Chitosan was also used to prepare chitosan/ tripolyphosphate nanoparticles (CH-TPP) by ionic gelation method and blended with HPMC to prepare edible films by solution casting method **[24].**

Other examples for property enhancement by adding chitosan are grease-proof paper with chitosan coating **[25],** Pulp fiber-chitosan sheets **[26],** biodegradable rice starch/chitosan films **[27],** chitosan/layered silicate Nano composite films **[28],** chitosan starch Films loaded with silver nanoparticles **[29]** and corn starch/chitosan composite films **[30].** In all cases mentioned above, it was observed that the Presence of chitosan enhanced the barrier and other properties of various Conventional and bio based polymers.

While the physicochemical properties of polymers are improved by the addition of chitosan, the hydrophilic nature of chitosan is a real drawback, which inhibits its contribution in packaging. Hence, the modification of existing bio based polymers has attracted much attention of researchers to overcome its limitations and it can be achieved by using many different techniques including copolymerization, grafting, grafting cum condensation polymerization or ring opening polymerization, etc.

Among various modification techniques used, Grafting, which can be achieved using various intermediates including free Radical, ions, photo-initiated grafting, plasma induced grafting and enzymatic grafting, has received significant attention **[31].**

3. Chitosan Derivatives and Their Application in Biomedicine

In recent years, many polymer compounds, extracted from starch, liver sugar, inulin, cellulose, chitin, and alginates, have been widely used in Biology, medicine, beauty, healthcare, and other fields **[32–33].**

Chitosan is a renewable natural alkaline polysaccharide that has no toxicity and no side effects, and it features good moisturizing and adsorption properties.

The United States Food and Drug Administration

(FDA) has approved that chitosan is safe in the use of Foods and drugs. However, chitosan is insoluble in water and most organic solvents, which limits its applications in various fields.

Chitosan derivatives can be obtained by the chemical modification of chitosan reactive functional groups.

Here, the −OH and $-NH_2$ active groups on the chitosan molecule are prone to chemical reactions **[34,35]**

4. Modification of Chitosan

Functional groups on the chitosan molecules include C_3–OH, C_6–OH, C_2–NH_2, and acetyl amino and glycoside bonds **[34].**

The chemical modification of chitosan can improve its physical and chemical properties, as well as expand its applications and relevant research fields **[36–37].**

A schematic diagram of chitosan modification is shown in **Figure 2.**

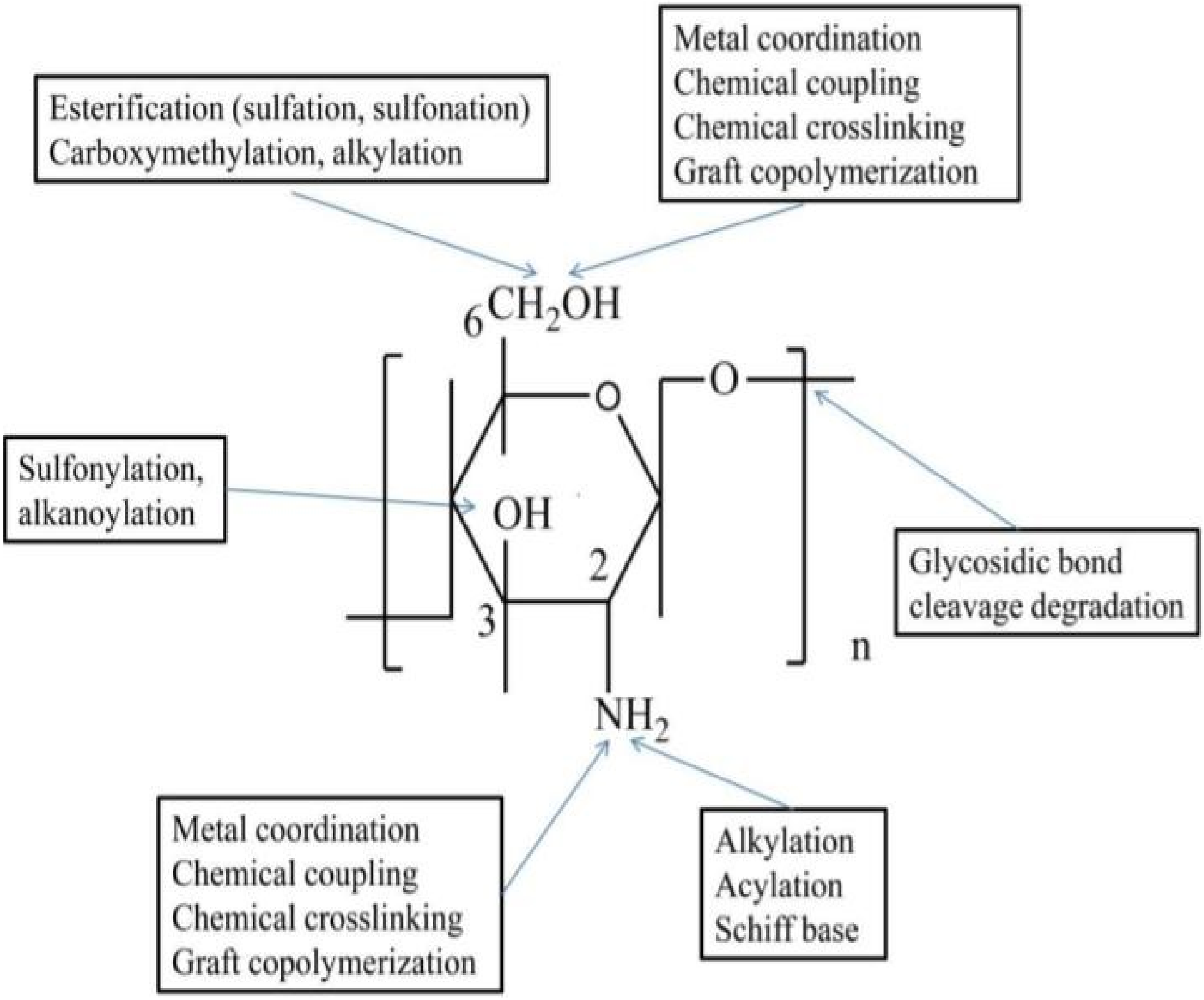


Figure 2. Schematic diagram of chitosan chemical reaction.

4.1 Acylated Modified Chitosan

Acylation modification is the most common modification of chitosan.

The acylation of chitosan refers to the reaction of chitosan with a variety of organic acids and derivatives of organic acids (mainly acetic anhydride and acyl chloride), introducing aliphatic or aromatic acyl groups to the Molecular chain **[38]** N-acylated chitosan derivatives show enhanced biocompatibility, anticoagulability, and blood compatibility.

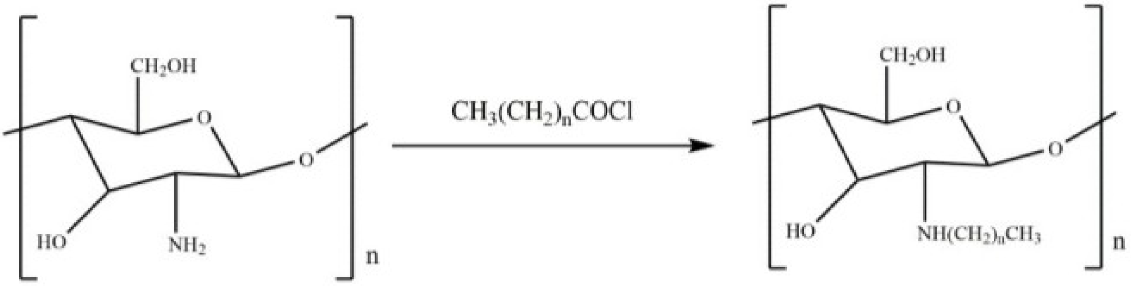
Moreover, N-acylated chitosan derivatives don’t cause an inflammatory reaction in the human body, so N-acylated chitosan can be used as a carrier or sustained release agent in Pharmaceutical applications **[39,40,41,42].**

The solubility of N-acylated chitosan depends on the degree of substitution (DS) and the length of the side chain **[40,34].**

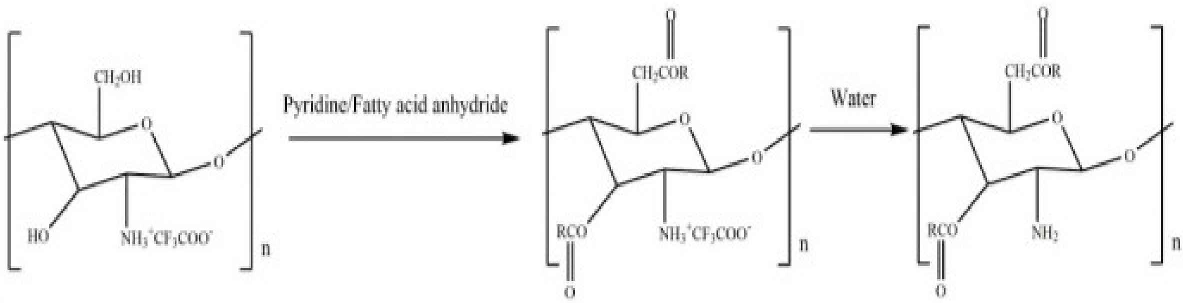
nacylated chitosan, with high solubility, can be used as a carrier for Hydrophobic drugs **[43],** while N-acylated chitosan, with high crystallinity, can increase fiber toughness and thermal stability, making it suitable for applications such as use in polyvinyl Chloride (PVC) fiber film materials **[44,45].** C_6–OH doesn’t react until C_2–NH_2 completely reacts **[46].**

If only O-acylated chitosan is required, it is necessary to add a solvent to protect the ammonium group, such as trifluoroacetic Acid or methanesulfonic acid **[47–48].**

O-acylation modification destroys the hydrogen bond structure of chitosan and improves its Fat solubility and hydrophobicity. However, the properties of O-acylated chitosan and N-acylated Chitosan are also different. O-acylated chitosan is lipid-soluble and can be dissolved in non-polar Solvents such as pyridine and chloroform **[47].**



A



B

Figure 3. Reaction equations for acylated chitosan derivatives. (A) N-acylated chitosan; (B) O-Acylated chitosan.

4.2 Alkylation Modified Chitosan

Alkylated chitosan can be used to prepare medical gauze due to its coagulation and antibacterial Properties **[49,50,51],** and it can be used to absorb anionic surfactants in water purification engineering due to its positive charge **[52].**

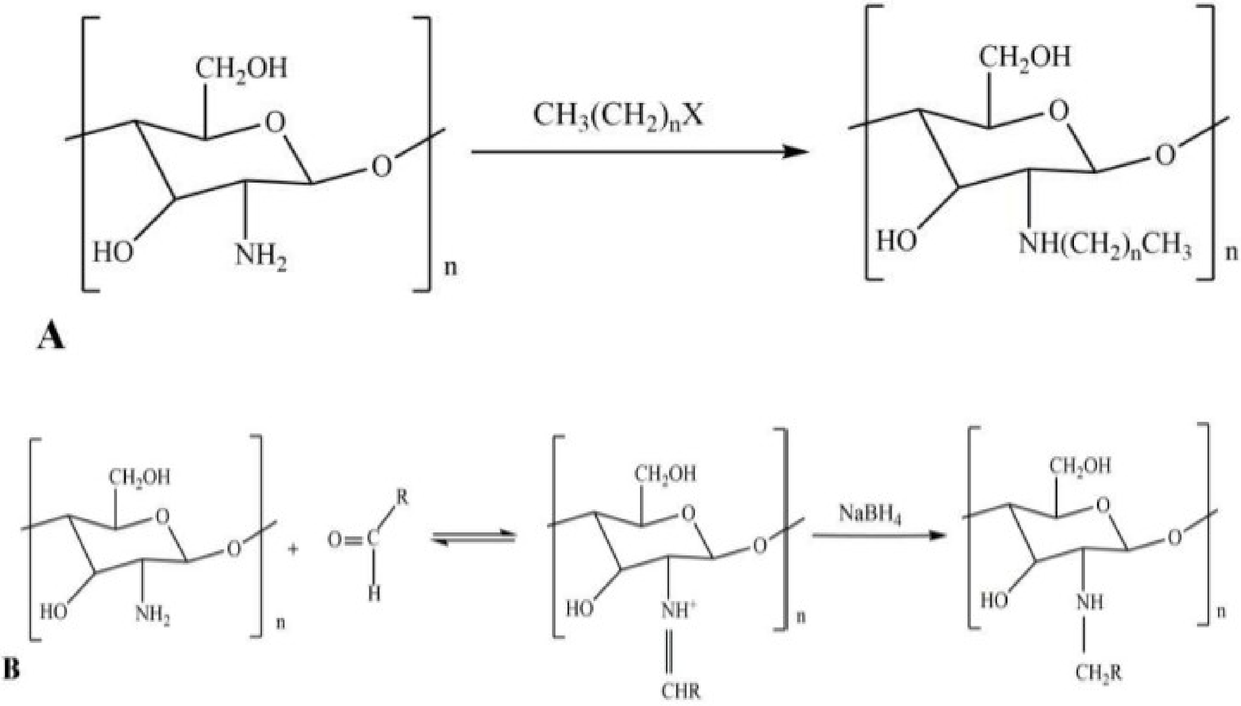


Figure 4. Alkylation chitosan derivative reaction equations. (A) Halogenated alkane to prepare N-Alkylated chitosan; (B) advanced fatty aldehyde prepares N-alkylated chitosan.

4.3 Carboxylated Chitosan

Carboxylated chitosan has wider Applications than chitosan in the industry, agricultural, medical, health, and biochemical fields **[50,52,53–54].**

CMCS is active in the biomedical and pharmaceutical fields due to its antibacterial properties, which promote wound healing, as well as its lipid lowering, anti-arteriosclerosis, antiviral, anti-tumor, anti-coagulation, and hypoglycemic effects **[55,56].**

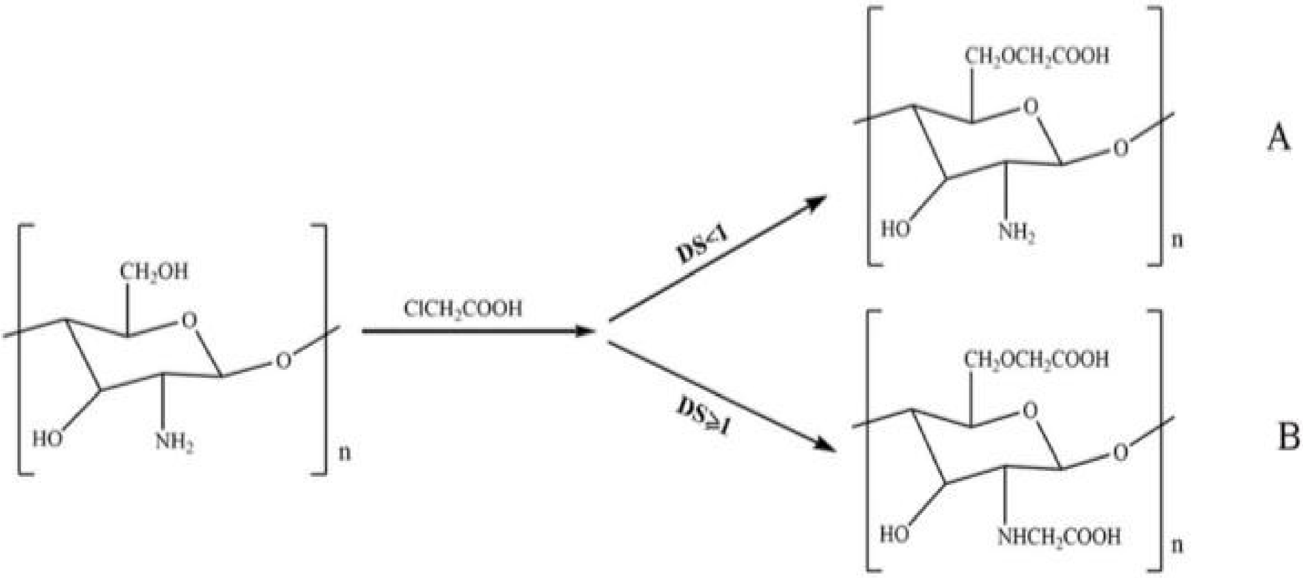
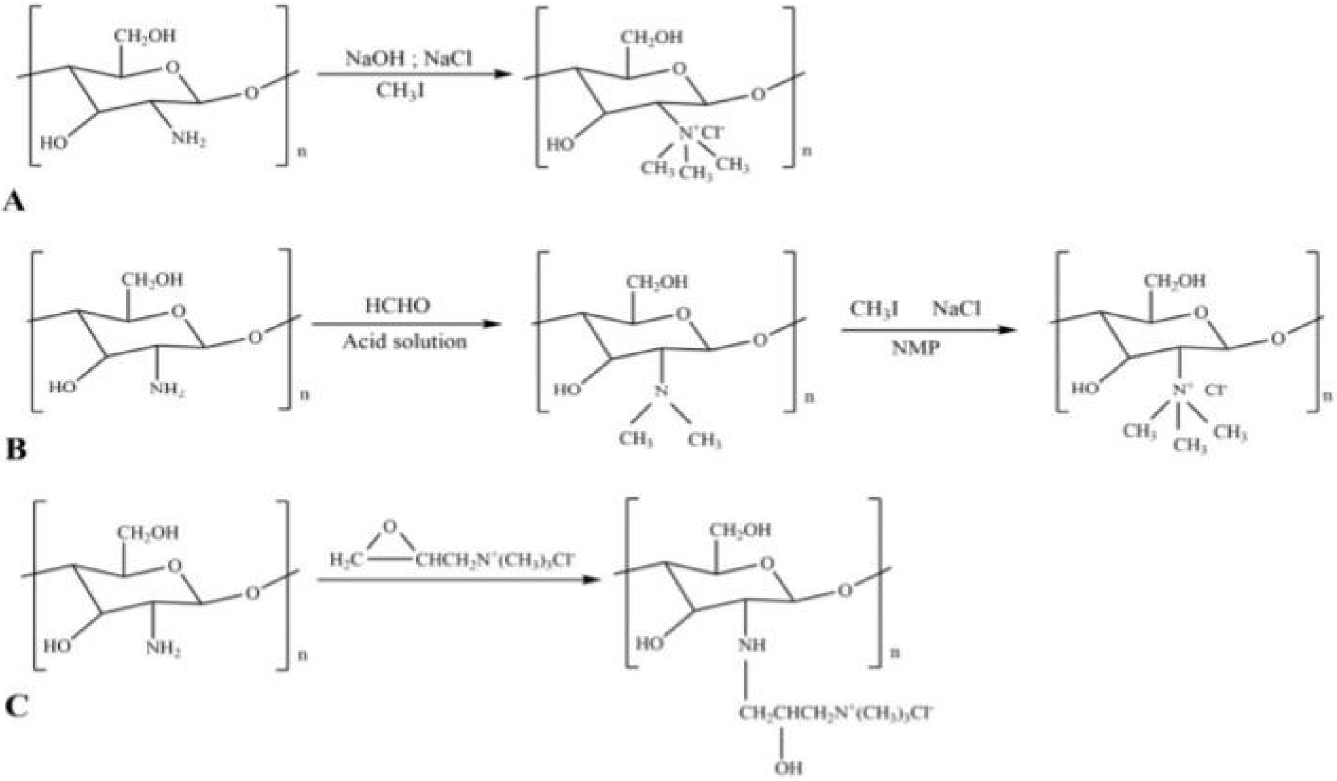


Figure 5. Carboxylates chitosan derivative reaction equation. (A) O-car boxy methyl chitosan (degree Of substitution (DS) < 1); (B) N, O-car boxy methyl chitosan (DS ≥ 1).

4.4 Quaternary Ammonium Chitosan

Quaternary ammonium chitosan salt also has better antibacterial, biocompatibility, biodegradability, non-toxicity, and biological effects, as well as innate mucoadhesiveness and the ability to penetrate mucus layers and bind to epithelial surfaces. Therefore, it is widely used in medicine **[57–58].**

Due to its antibacterial properties, quaternary ammonium chitosan can be used in anti-inflammatory drugs or as a filler fiber in materials for dressing wounds



[58,59].

Figure 6. Reaction equations for quaternized chitosan derivatives. (A), N,N-trimethyl chitosan (TMC) direct quaternary ammonium salt substitution method; (B) TMC N-alkylation; (C) chitosan 2,3-epoxypropyl trimethyl ammonium
chloride (GTA) ring opening method

5. Chitosan-Polyphenol Conjugates for Human Health

Polyphenols are naturally occurring secondary metabolite micronutrients in plants, which contain hydroxyl groups in their aromatic ring **[60–61].**

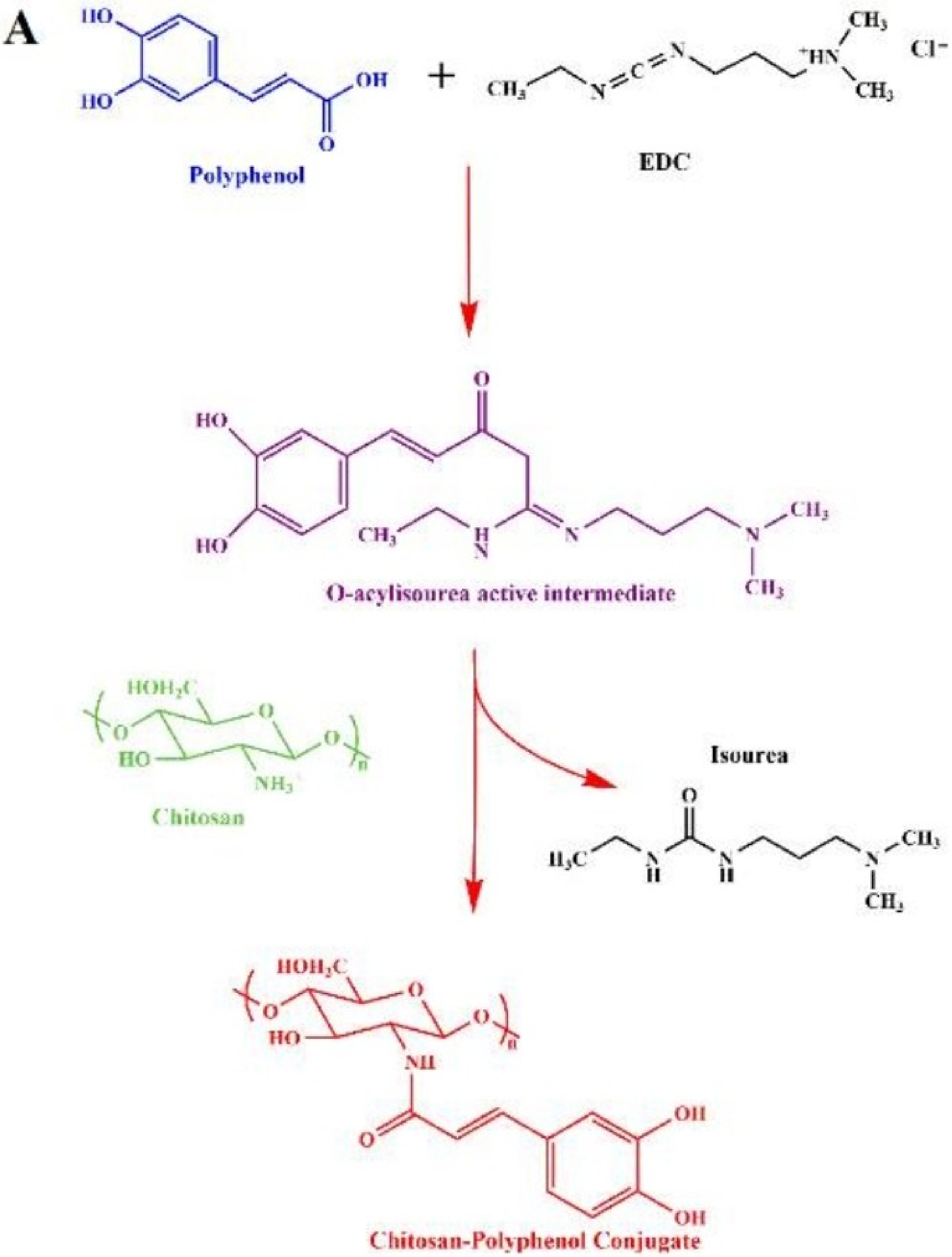
Polyphenols form a natural defense system for plants, protecting them from UV radiation and pathogenic invasion, and are also responsible for oxidative stability and organoleptic properties **[62–63].**

Polyphenols attract immense attention for their potential nutraceutical and pharmaceutical impacts on human health, due to their inherent biological properties such as antioxidant, anti-allergic, antibacterial, anti-inflammatory, antitumor, anti-diabetic, and antiviral **[64–65].**

They also keep blood vessels healthy and flexible by managing blood pressure levels that is helpful for good blood circulation **[66–67].**

- **Polyphenol limitations:**
  1. Low bioavailability
  2. Short biological shelf life
  3. Rapid metabolism in body.
- **Chitosan limitations:**
  1. Poor water insolubility
  2. Faster enzymatic degradation in body
  3. Non-availability of H atom donor
- **Chitosan -polyphenol conjugates advantages**
  1. Higher solubility
  2. Extended shelf life
  3. Increased bioavailability

4. Higher antioxidant effect
5. Synergistic anti-bacterial activity



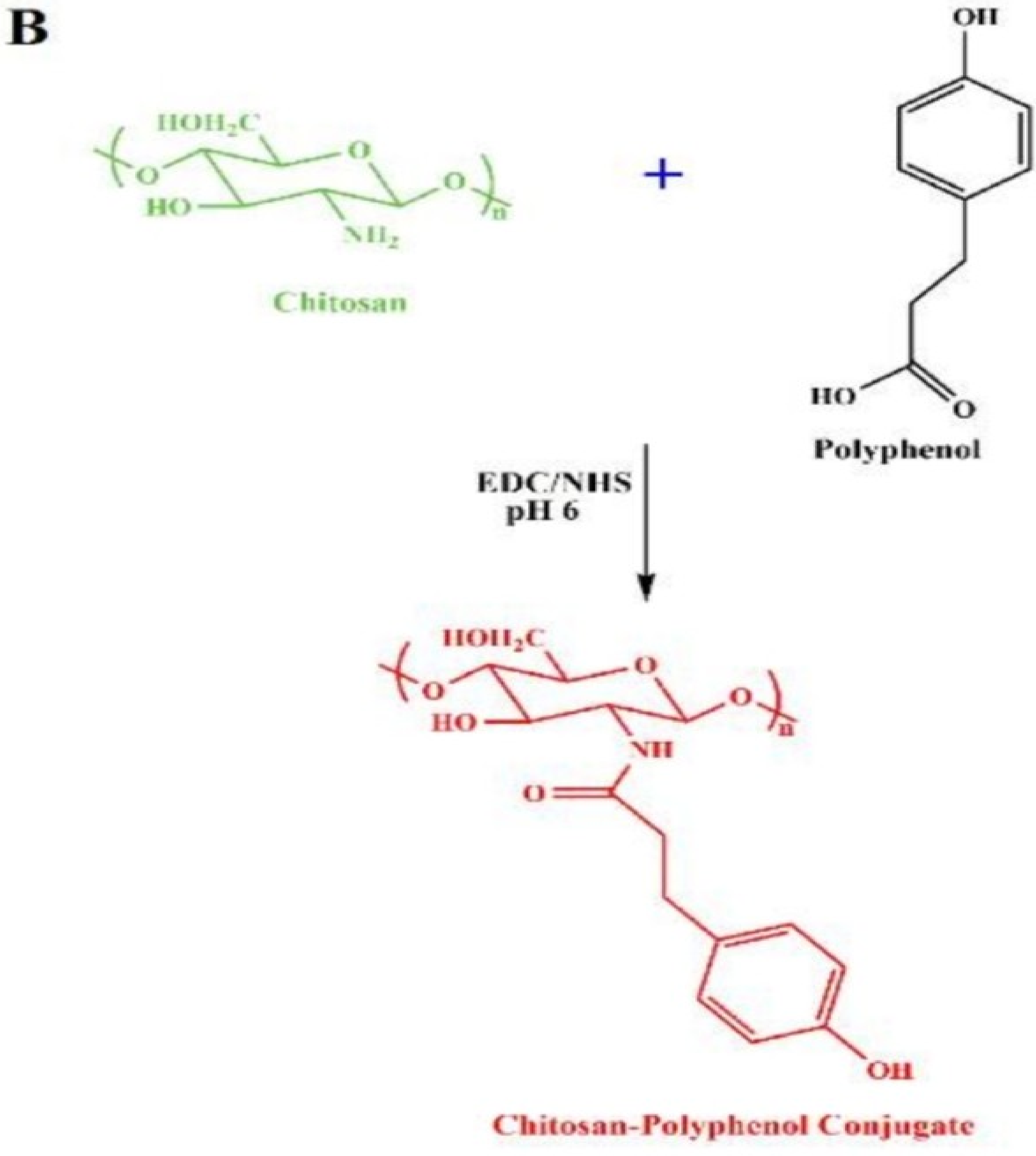


Figure 7. Proposed mechanism for chemical synthesis of polyphenol-chitosan conjugate (A) using Only EDC, adapted with

permission from Ref. [101], © 2022 The Society for Biotechnology, Japan, Elsevier B.V. (B) using EDC/NHS, adapted with permission from Ref. [102], © 2022 The Royal Society Of Chemistry.

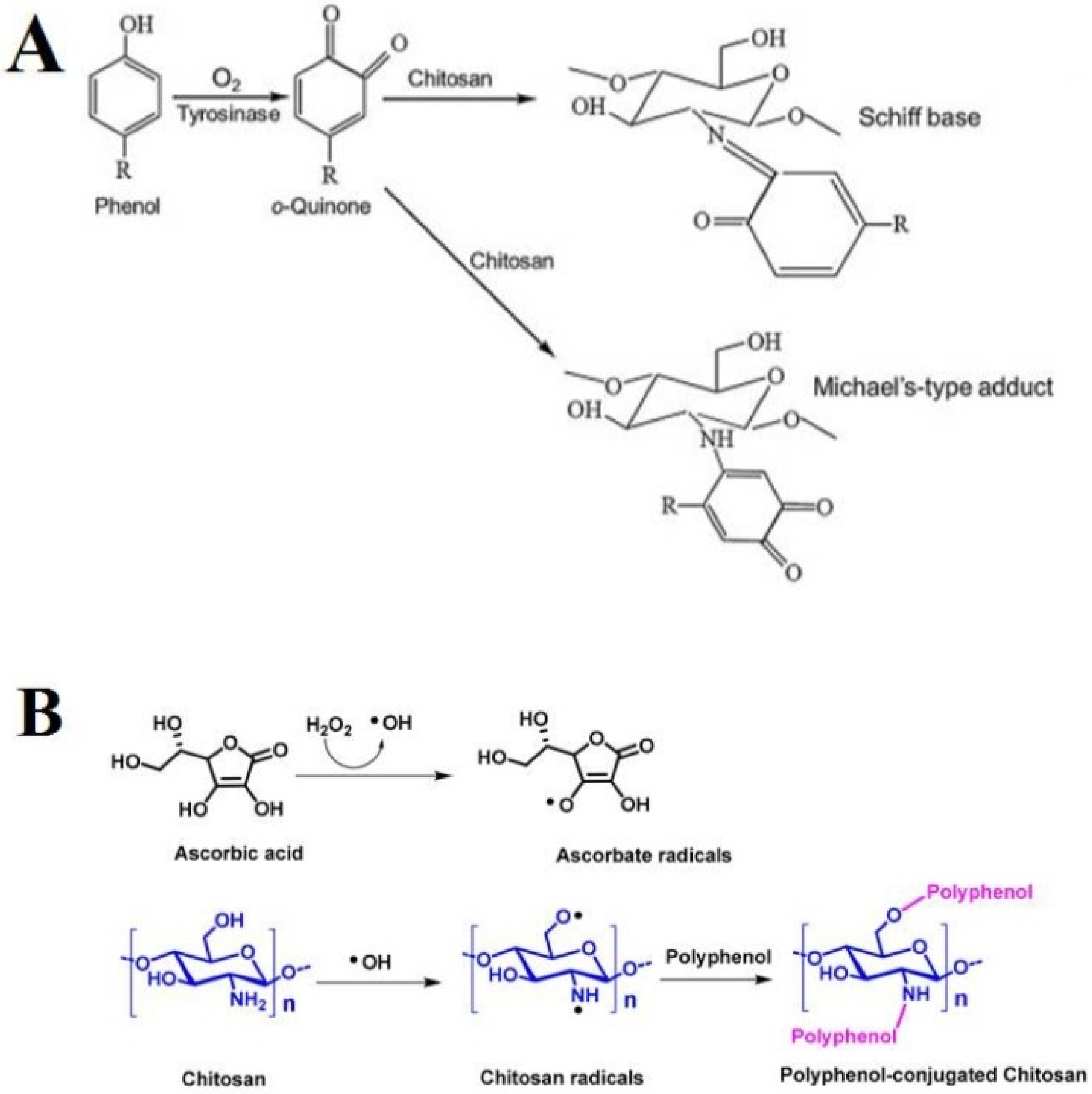


Figure 8. Proposed mechanism for polyphenol-chitosan conjugate through (A) enzyme-mediated Strategy , and (B) free radical in Duced reaction .

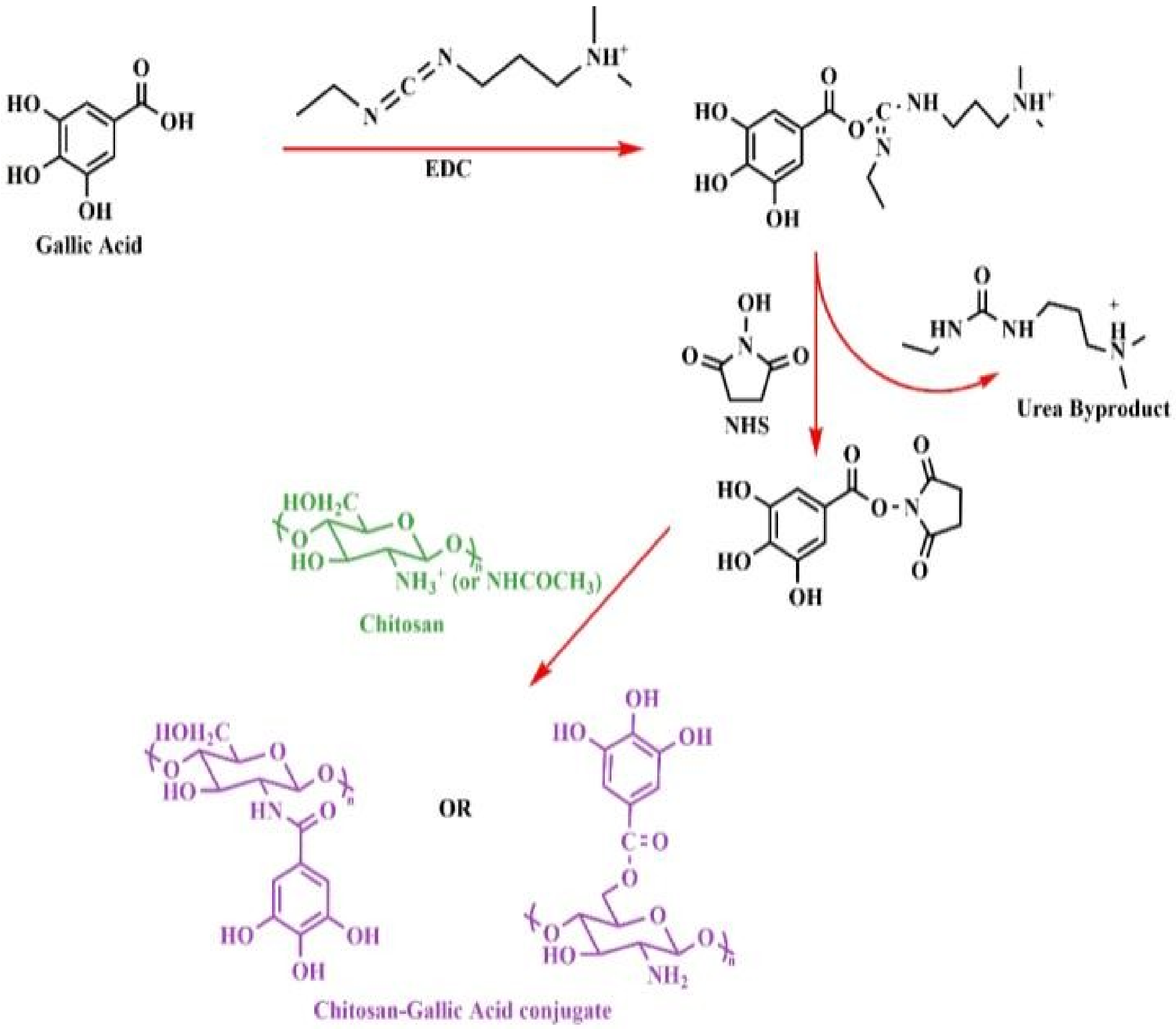


Figure 9. Ester modification synthesis of chitosan-GA conjugation

6. Synthesis and characterization of new functionalized chitosan and its antimicrobial and in-vitro release behavior from topical gel

Heterocyclic nitrogen-containing compounds:

(Including the five-membered Benzimidazole and thiadiazole moieties) are distinguished as an outstanding and valuable source of chemotherapeutic agents.

More than 75% of the drugs authorized by the Food and Drug administration and currently available in the pharmaceutical market belong to this group of therapeutic compounds **[68].**

benzimidazole is one of the most famous and biologically active Members of the heterocyclic group and is found in many synthetic and Natural therapeutic agents such as: anticancer, antimicrobials, antioxidants, **[69, 70].**

Recently, various benzimidazole based thiadiazole and triazole derivatives have been recorded as efficient anti-microbial agents **[71].**

Chitosan has outstanding chemical and physical properties and is non-toxic, biocompatible, and biodegradable **[72, 73]**.

Chitosan and its derivatives have broad antimicrobial activity against Gram-negative bacteria, Gram-positive bacteria, and fungi.

Therefore, chitosan is widely used as an antibacterial agent **[74].**

The antimicrobial potential of chitosan can be attributed to inhibiting DNA replication, interfering with the bacterial cell wall, and chelating essential minerals, which prevents the uptake of extracellular nutrients and affects cell permeability.

Moreover, it can be used as an effective source of new biocides and antiviral agents. Recently, the potential application of chitosan and chitin as a proposed therapy for the new coronavirus is being studied **[75,76].**

Topical delivery of the drug can improve its bioactivity by reducing its side effects, enhancing its penetration, ease of administration, increasing patient compliance, and enhancing its therapeutic efficacy

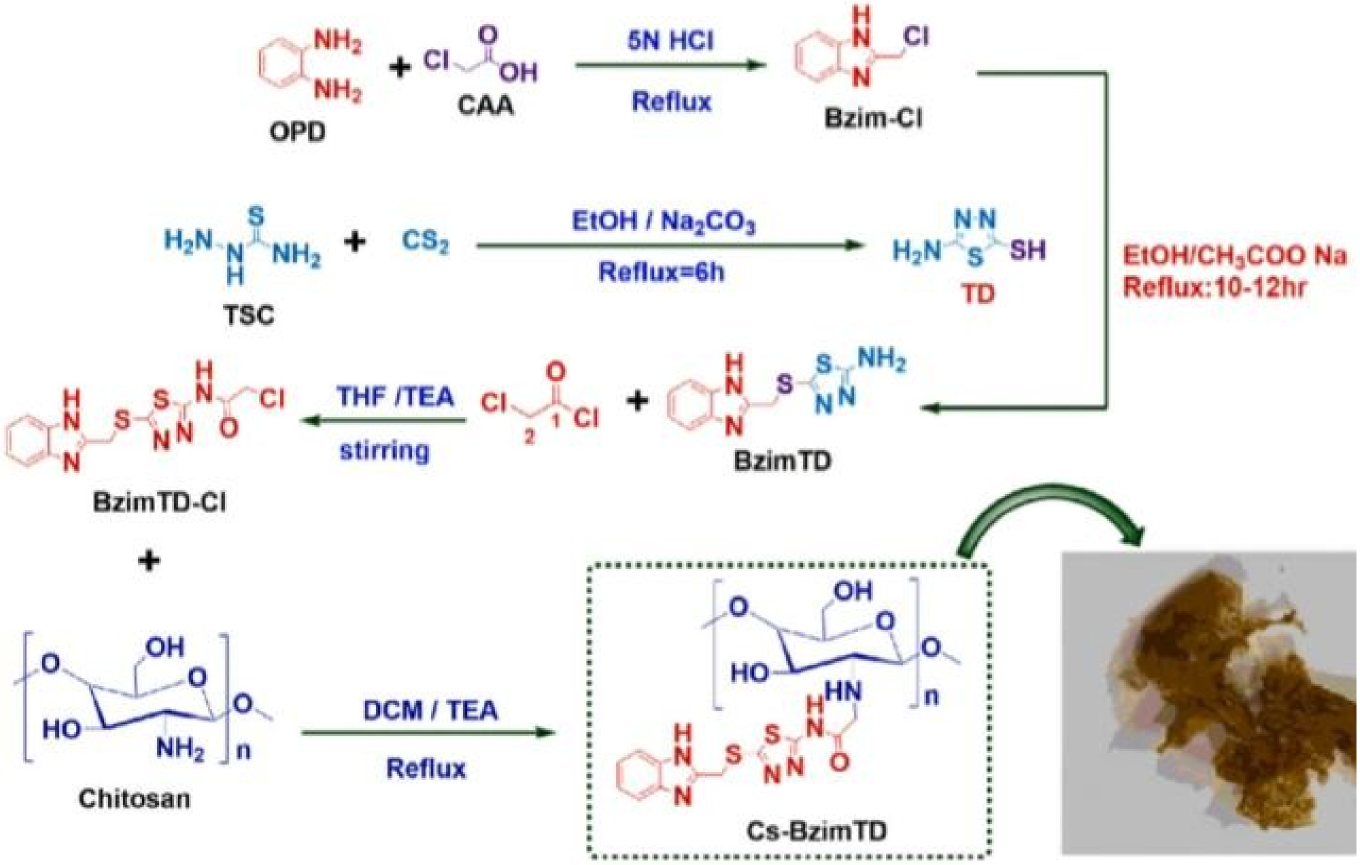
[77].

The topical gels provide suitable drug delivery because they are thixotropic, less greasy, easily spreadable, easy to remove topical formulations involve the release of the drug from the formula followed by penetration through the skin to reach the target tissue or cell.

The release of the drug from topical preparations depends on the physicochemical properties of the polymer used and the active drug **[78–80]**.

One of the most easily accessible organs of the human body Skin, so it has become the main route of delivery of topical drugs.

There are a large number of medicinal products it is applied to the skin or mucous membrane which either reinforces or restores the primary function of the skin **[81]**



Scheme 1. Synthesis route of Thiadiazole functionalized chitosan (Cs-BzimTD).

OPD	Ortho Phenyl Diamine
CAA	Choloro Acetic Acid
TSC	Thiosemi carbazide
TD	Thisol diamine

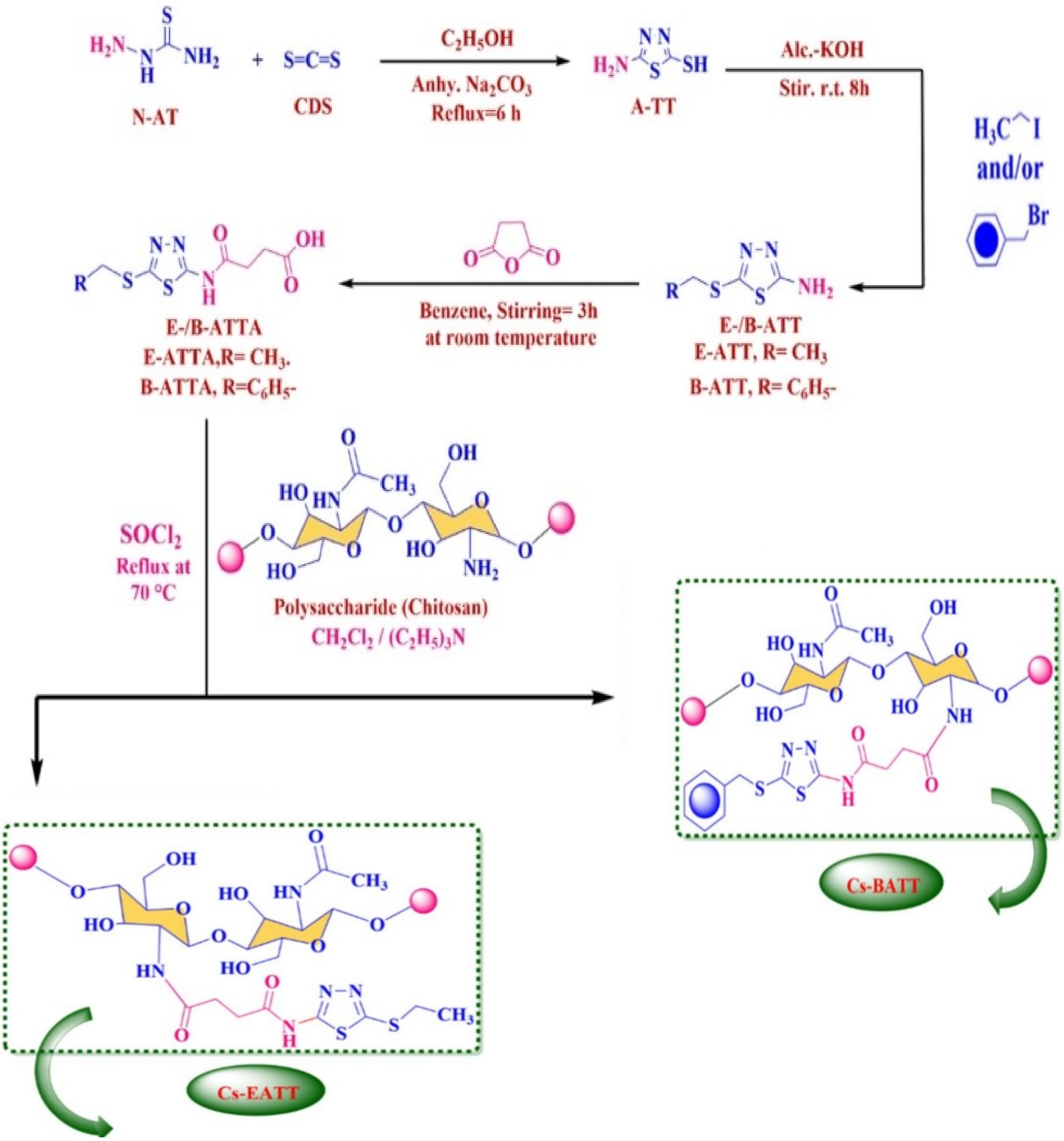
7. 1,3,4-thiadiazole modified chitosan:

Thiadiazoles are heterocycle group with a five membered ring that possesses sulfur and two nitrogen atoms and exhibit a broad range of biological activities **[82, 83].**

A significant number of molecules bearing the thiadiazole moiety have a variety of biological characteristics, such as antimicrobial **[84, 85],** anti-proliferative **[86],** antitumor **[87],** anti-tubercular **[88],** anti-inflammatory **[89],** anticonvulsant **[90],** antioxidant **[91],** anti-leishmanial **[92],** antibacterial **[93, 94],** antiviral **[95],** analgesic **[96]**, antipsychotic **[97],** antihistamine **[98],** anti-depressive **[99],** and antihypertensive **[100].**

For example, two new polymers designated as Cs-EATT and Cs-BATT have been synthesized via linking the chitosan with the synthesized 1,3,4-thiadiazole compounds.

The synthesized polymers exhibit high activity to control the growth of pathogenic bacteria (Staphylococcus aureus, Bacillus subtilis, Esherichia coli, and Pseudomonas aeruginosa), and unicellular fungi (Candida albicans).



Scheme 2. Synthetic diagrams of major reactions occurring during the syntheses of Chitosan derivatives

8. Natural Gum Based Composites: Chemical Modification, Property Evaluation and Applications

The natural gums are non-toxic, biodegradable and low cost polysaccharide, which offer many benefits over fossil based synthetic polymers due to their stabilizing and emulsifying properties.

As a result, they are applicable in various areas such as pharmaceuticals, adhesives, films, paints **[101].**

Gum Arabic (GA) is one of the natural complex polysaccharides, derived from an exudate of Acacia trees the other existing gums are guar gum (GG) **[102].**

Guar gum (GG) is a non-ionic natural polysaccharide sourced from the seeds of cyamopsis, guar gum is used in many applications in industries such as, textile, petroleum, paper, food, explosives and pharmaceuticals it is biocompatible, biodegradable, non-toxic, low-cost and amenable to chemical modification.

Carboxy methyl guar gum was formulated as micro particles tailored for drug delivery applications **[102]**

8.1 Preparation of carboxymethyl guar gum

The synthesis of carboxymethyl guar gum was performed as previously reported (Dodi et al., 2011) with slight modifications.

Briefly, 1 g of GG was dispersed in 100 mL of ultrapure water and the Mixture was stirred for 2 h under nitrogen atmosphere.

The resulting suspension was mixed with 20 mL of NaOH solution (0.1 M) and the mixture was allowed to react for 2 h at room temperature (25°C).Chloroacetic acid (20 mL; 1.58 g/cm3; 0.025 mol) was added and the mixture was stirred overnight at 50° C.

The reaction mixture was then cooled to ambient temperature, adjusted to pH 7.0 (using 1 M HCl), extracted with acetone and separated by centrifugation (5 000 rpm; 6142 RCF; 10 min).

The Product was further purified by dialysis against distilled water until neutral pH has been reached (approx. 72 h).

The final product (batch denoted CMGG) was then dried by lyophilisation and stored in a desiccator for further analysis**. [103]**

9. Electrical Conductivity of Oxadiazole and Triazole Polymer Content

The field of electrically conducting polymers has been developed very rapidly since the discovery of intrinsically conducting polymers **[104].**

It was noticed that the electrical conductivity of organic Conjugated polymers was increased by many order of magnitude when they are doped with oxidizing or reducing agents **[105].**

The doped polymers have been concept as an organic metal or semiconductors **[106]**.

The chemical structure of the conjugated polymers is confirmed of Π electron system extending over long chain of monomer unit **[107]**.

This extending of Π system gives the susceptibility of the oxidation and reduction with the electrical conductivity **[108]**.

By controlling the oxidation or reduction processes, the electrical conductivity and optical properties of the polymer can be controlled. It is well known that the undoped conjugated polymers are established as intrinsic semiconductors **[109].**

The value N- the electrical conductivity is depend on the energy gap Between HOMO and LUMO levels.

Where by the energy gap in these types of polymers depend on the Constitution of their backbone and on the nature of side substituents **[110]**.

The presence of some heteroatoms within the carbon backbone conjugated polymers can enhanced the conjugated through the delocalization of their lone pair of electron with the conjugated system.

On the Other hand the heteroatoms (N, S, O) provide sets for hosting the dopant molecules **[111].**

In the last decade, polymers containing heterocyclic ring can be considered as an electron donor or electron Acceptor **[112,113] .**

The electrical properties of the oxadiazole polymers were developed by loading the Polymer on graphene Nano sheet **[114]**.

The conjugated polymers that containing oxadiazole or triazole rings were used for building organic photovoltaic cells and their efficiency was enhanced by mixing the Polymer with Nano carbon tube **[115].**

In this work different polymers with oxadiazole and triazole heterocyclic ring have been prepared to prove the effects of chemical structure on the electrical conductivity.

On the other hand, the ability to Doping was studied by different dopant.

The electrical conductivity of the conjugation polymers can be affected by different factors.

The Presence of long aliphatic segment within the back bone of the polymer chain can increased the electrical conductivity of the polymer by increasing the flexibility.

On the other hand the presence of aliphatic segment interrupts the conjugation and decrease the electrical conductivity.

The presence of the hetero atoms in the main chain of the polymer will enhance the electrical conductivity by the Participation of the lone pair of electron of the hetero atoms in the conjugation system.

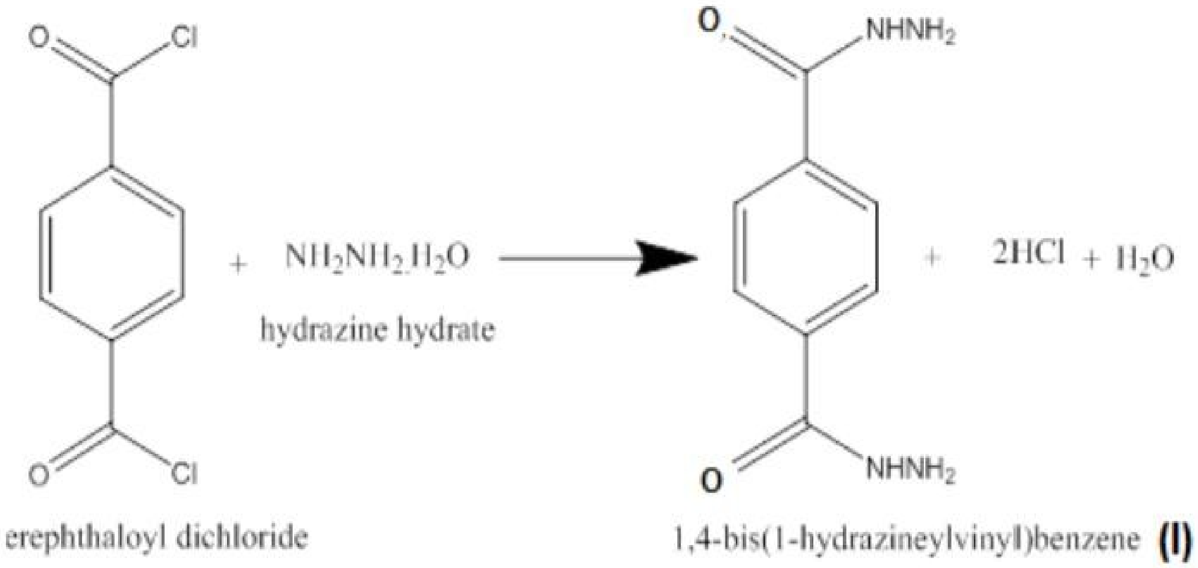
Also hetero Atoms can be considered as a site to host the dopant molecule and create the charge carriers.

Synthesis of 1, 4-bis (1-hydrazineylvinyl)benzene (I):

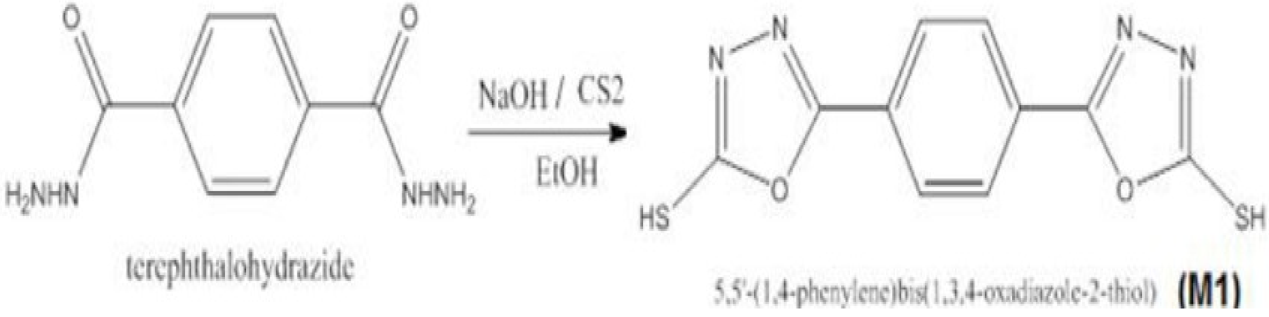
In a round bottom flask contain 20ml of hydrazine hydrate and 2ml dry dioxane, adding drop wise a solution of 6.5g (0.03mole) of terephthaloyl chloride dissolved in 6ml dry dioxane at room temperature.

The mixture was refluxed for extra 2 hrs.

The yellow precipitate was filtered, washed with ethanol and dried under vacuum.



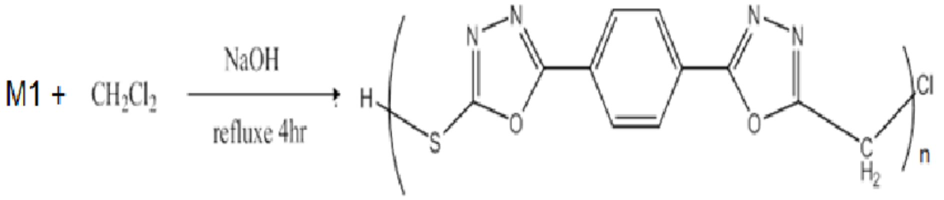
Scheme 3. Synthesis of 1,4-bis (1-hydrazineylvinyl)benzene (I)



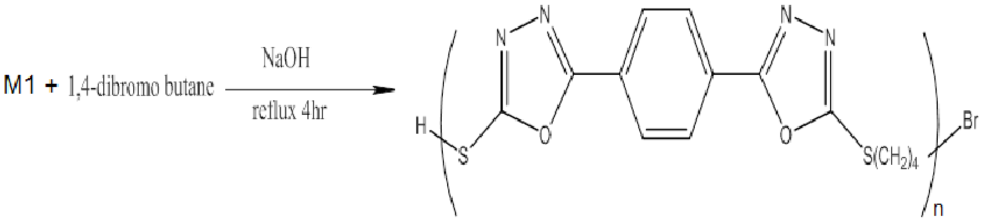
Polymer preparations:

Polymer I: 1.43g (0.005mole)of M1 was dissolved in 0.1M NaOH solution.0.42ml of dichloromethane was added drop wise and the reaction mixture was refluxed for of 4hrs .

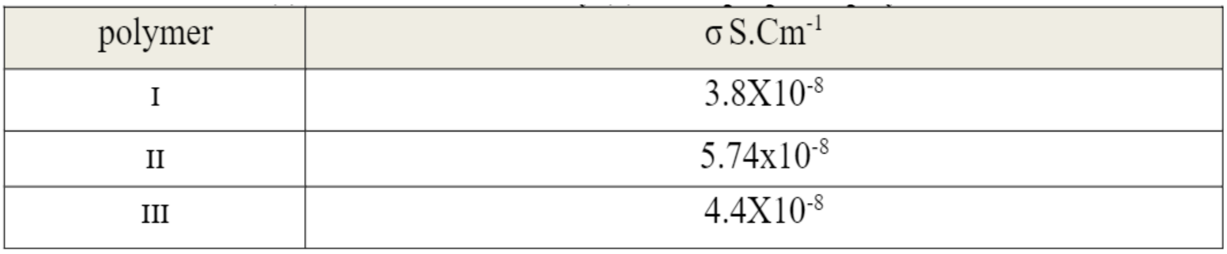
The produced yellow polymer was filtered and dried under vacuum.



Polymer II: The same procedure for preparation polymer I was followed by polymerization of M1with 1.07ml of dibromobutane.



Polymer III



polymer	σ S.Cm^{-1}
I	$3.8X10^{-8}$
II	$5.74x10^{-8}$
III	$4.4X10^{-8}$

The results indicate that the major factor effect on conductivity is the chemical structure of the polymer.

It was noticed that the electrical conductivity of polymer III is higher than that of polymer I

10. Organic Conductor:

Organic conductors may be divided into two groups:

Low molecular weight compounds charge transfer complexes and salts of radical ions, such as the complex of tetracyanoquinodimethane (TCNQ).

The conductivity in these compounds is due to the radical anions of TCNQ and neutral TCNQ molecules.

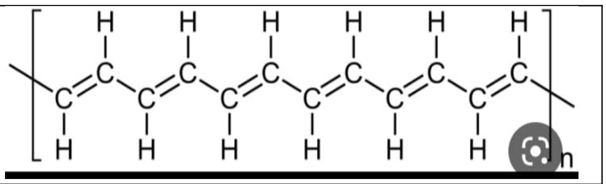
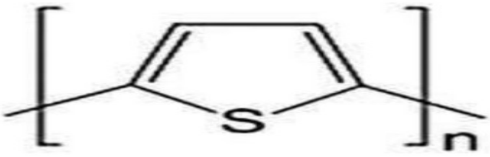
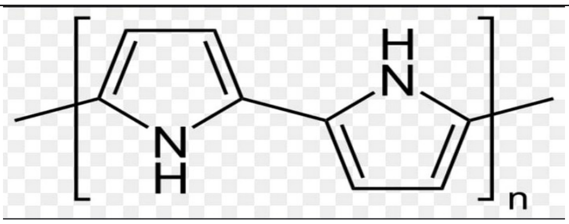
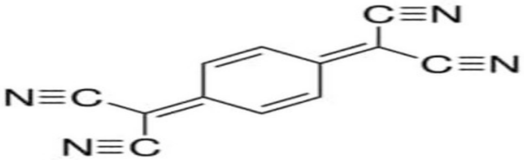
The counterions serve only to neutralize the charge and do not contribute to the conductivity.

Polymers with conjugated unsaturated double bonds.

These systems must be either partially reduced or oxidized to provide conductance.

Since the beginning of conductive polymer technology there has been an intensive effort to improve the properties of these polymers.

This work is ongoing and has produced new chemistries and structures that have resulted in the patenting and introduction of a succession of substances, e.g. polyacetylene, polypyrrole and polythiophene **[116]**.

polyacetylene	
polythiophene	
polypyrrole	
tetracyanoquinodimethane	

11. Conducting Polymers

A key property of a conductive polymer is the presence of conjugated double bonds along the backbone of the polymer.

In conjugation, the bonds between the carbon atoms are alternately single and double.

Since the electrons in a conjugated system are only loosely bound, electron flow may be possible.

Every bond contains a localized "sigma" bond which forms a strong chemical bond.

In addition, every double bond also contains a less strongly localized "a" bond which is weaker.

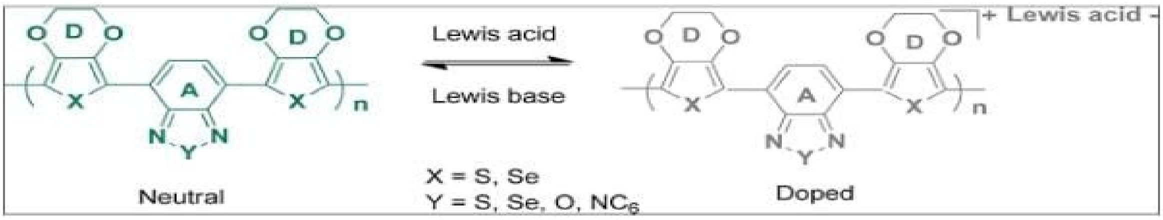
These enable the electrons to be delocalized over the whole system and so be shared by many atoms.

This means that the delocalized electrons may move around the whole system.

However, conjugation is not enough to make the polymer material conductive.

In addition, the polymer material needs to be doped for electron flow to occur.

Doping is either the addition of electrons (reduction reaction) or the removal of electrons (oxidation reaction) from the polymer, for example :



An oxidation doping (removal of electrons) can be done using iodine.

The iodine attracts an electron from the polymer from one of the bonds.

Once doping has occurred, the electrons in the bonds are able to "jump" around the polymer chain.

As the electrons are moving along the molecule, electric current occurs.

For better conductivity the molecules must be well ordered and closely packed to limit the distance "jumped" by the electrons.

The conductivity of conducting polymers can be tuned by chemical manipulation of the polymer backbone, by the nature of dopant, degree of doping, and blending with other polymers **[117].**

12. Applications of conductive polymers

The principal interest in the use of polymers is in low-cost manufacturing using solution-processing of film-forming polymers.

Light displays and integrated circuits, for example, could theoretically be manufactured using simple inkjet printer techniques **[118-122].**

- polyaniline is used as a conductor and for electromagnetic shielding of electronic circuits.
- Polyaniline is also manufactured as a corrosion inhibitor.
- Poly(ethylenedioxythiophene) (PEDOT) doped with polystyrene sulfonic acid is manufactured as an antistatic coating material to prevent electrical discharge exposure on photographic emulsions and also serves as a hole injecting electrode material in polymer light-emitting devices.Poly (phenylene vinylidene) derivatives have been major candidates for the active layer in pilot production of electroluminescent displays (mobile telephone displays).
- Poly (dialkylfluorene) derivatives are used as the emissive layer in full-color video matrix displays.
- Poly (thiophene) derivatives are promising for field-effect transistors: they may possibly find a use in supermarket checkouts.
- Poly (pyrrole) has been tested as microwave-absorbing "stealth" (radar-invisible) screen coatings and also as the active thin layer of various sensing devices.Other possible applications of conductive polymers include super capacitors and electrolytic-type capacitors.

Some conductive polymers such as polyaniline show a whole range of colors as a result of their many protonation and oxidation forms, Their electrochromics properties can be used to produce, e.g "smart windows"

An advantage over liquid crystals is that polymers can be fabricated in large sheets and unlimited visual angles.

They do not generally respond as fast as in electron-gun displays, because the dopant needs time to migrate into or out from the polymer but still fast enough for many applications **[123].**

13. Conclusion

In this work we concentrated on functional polymer as its low cost, ease of processing, and attractive features of functional, one of the most interesting polymers is chitosan.

Chitosan consider as biodegradable polymers and Chitosan is a product of the deacetylation of chitin, chitosan contains active functional groups that are liable to chemical reactions thus, chitosan derivatives can be obtained through the chemical modification of chitosan. The modification of chitosan has been an important aspect of chitosan research, showing a better solubility, pH-sensitive targeting, and an increased number of delivery Systems.

Also, Chitosan has been conjugated with polyphenols to overcome the limitations of both chitosan and polyphenol, along with increasing the potential synergistic effects of their combination for therapeutic applications.

Recently, chitosan and its derivatives have been gaining more attention due to their high integration into various biomedical applications.

Herein, a new chitosan derivative was prepared by linking the chitosan (Cs) with a novel heterocyclic compound, benzoimidazol thiadiazole (BzimTD) to form Cs-BzimTD and two new polymers designated as Cs-EATT and Cs-BATT have been synthesized via linking the chitosan with The synthesized 1,3,4 thiadiazole compounds.

Furthermore, natural macromolecules for example the guar gum and gum Arabic play an important role in the modification of macromolecules especially in medical and industrial applications.

Finally we explained the electrical conductivity of oxadiazole and triazole polymer content.

15. الملخص العربي

ركزنا في هذا العمل علي المجموعات الوظيفيه للبوليمرات نظرا لسهوله معالجتها وأنها اكثر فاعليه في الكثير من المجالات ،واحد اهم هذه البوليمرات هو الكيتوزان

لانه يحتوي علي مجموعات وظيفيه فعاله مثل (OH,NH2)التي تجعله سهل التعديل بواسطه التفاعلات الكيميائية المختلفه وكان تعديل الكيتوزان جانبا مهما في أبحاث الكيتوزان ، حيث أظهر قابلية أفضل للذوبان ، واستهداف حساس لدرجة الحموضة ، وعدد متزايد من أنظمة التوصيل.

أيضًا ، تم اقتران الشيتوزان بالبوليفينول للتغلب على قيود كل من الشيتوزان والبوليفينول ، جنبًا إلى جنب مع زيادة التأثيرات التآزرية المحتملة لتوليفاتهما للتطبيقات العلاجية.

في الآونة الأخيرة ، اكتسب الشيتوزان ومشتقاته مزيدًا من الاهتمام بسبب تكاملها العالي في مختلف التطبيقات الطبية الحيوية.

هنا ، تم تحضير مشتق جديد من الشيتوزان عن طريق ربط الشيتوزان (Cs) بمركب حلقي غير متجانس جديد ، وهو Benzoimidazol thiadiazole (BzimTD) لتشكيل Cs-BzimTD وتم تصنيع اثنين من البوليمرات الجديدة المعينة باسم Cs-EATT و Cs-BATT عن طريق ربط الشيتوزان مع مركبات ثياديازول المركب 1،3،4.

علاوة على ذلك ، تلعب الجزيئات الكبيرة الطبيعية مثل صمغ الغار والصمغ العربي دورًا مهمًا في تعديل الجزيئات الكبيرة خاصة في التطبيقات الطبية والصناعية.

أخيرًا شرحنا التوصيلية الكهربائية لمحتوى بوليمر أوكساديازول وترايازول.

References

1. L. S. Nair, C. T. Laurencin, Biodegradable polymers as biomaterials, Prog. Polym. Sci. 32, 762–798, 2007.

2. C. Deng, Y. Jiang, R. Cheng, F. Meng, Z. Zhong, Biodegradable polymeric Micelles for targeted and controlled anticancer drug delivery: Promises, Progress and prospects, Nano Today 7, 467–480, 2012.

3.R. N. Tharanathan, Biodegradable films and composite coatings: Past, pres-Ent and future, Trends Food Sci. Technol. 14, 71–78, 2003.

4. A. K. Mohanty, M. Misra, L. T. Drzal, Sustainable bio-composites from Renewable resources: Opportunities and challenges in the green materials World, J. Polym. Environ. 10, 19–26, 2002.

5. G.-Q. Chen, A microbial polyhydroxyalkanoates (PHA) based bio- and Materials industry, Chem. Soc. Rev. 38, 2434–2446, 2009.

6. M. Dash, F. Chiellini, R. M. Ottenbrite, E. Chiellini, Chitosan—A versatile Semi-synthetic polymer in biomedical applications, Prog. Polym. Sci. 36, 981–1014, 2011.

7. V. Zargar, M. Asghari, A. Dashti, A review on chitin and chitosan polymers: Structure, chemistry, solubility, derivatives, and applications, Chem. Bio. Eng. Rev. 2, 204–226, 2015.

8. Z. Karim, A. P. Mathew, M. Grahn, J. Mouzon, K. Oksman, Nanoporous Membranes with cellulose nanocrystals as functional entity in chitosan:Removal of dyes from water, Carbohydr. Polym. 112, 668–676, 2014.

9. T. R. A. Sobahi, M. Y. Abdelaal, M. S. I. Makki, Chemical modification of Chitosan for metal ion removal, Arab. J. Chem. 7, 741–746, 2014.

10. W. Zhang, J. Zhang, Q. Jiang, W. Xia, The hypolipidemic activity of chitosan Nanopowder prepared by ultrafine milling, Carbohydr. Polym. 95, 487–491, 2013.

11. T. Uragami, T. Saito, T. Miyata, Pervaporative dehydration charac-Teristics of an ethanol/water azeotrope through various chitosan Membranes, Carbohydr. Polym. 120, 1–6, 2015.

12. D. Chen, B. Hu, C. Huang, Chitosan modified ordered mesoporous silica As micro-column packing materials for on-line flow injection-inductively Coupled plasma optical emission spectrometry determination of trace heavy Metals in environmental water samples, Talanta 78, 491–497, 2009.

13. E.P. Minet, C. O'Carroll, D. Rooney, C. Breslin, C.P. McCarthy, L. Gallagher, K.G. Richards, Slow delivery of a nitrification inhibitor (dicyandiamide) to soil Using a biodegradable hydrogel of chitosan, Chemosphere 93, 2854–2858, 2013.

14. P. Chantarasataporn, P. Tepkasikul, Y. Kingcha, R. Yoksan, R. Pichyangkura,W. Visessanguan, S. Chirachanchai, Water-based oligochitosan and Nanowhisker chitosan as potential food preservatives for shelf-life extension
Of minced pork, https://doi.org/10.1016/j.foodchem.2014.03.019.

15. J.P. Quiñones, K.V. Gothelf, J. Kjems, Á.M.H. Caballero, C. Schmidt, C.P. Covas, N,O6-partially acetylated chitosan nanoparticles hydrophobically-modified for controlled Release of steroids and vitamin E, Carbohydr. Polym. 91, 143– 151, 2013.

16. Y.A. Gomaa, L.K. El-Khordagui, N.A. Boraei, I.A. Darwish, Chitosan mic-Roparticles incorporating a hydrophilic sunscreen agent, Carbohydr. Polym. 81, 234–242, 2010.

17. N. Mati-Baouche, P.-H. Elchinger, H. de Baynast, G. Pierre, C. Delattre, P.Michaud, Chitosan as an adhesive, Eur. Polym. J. 60, 198–212, 2014.

18. J.-P. Wang, Y.-Z. Chen, S.-J. Yuan, G.-P. Sheng, H.-Q. Yu, Synthesis and char Acterization of a novel cationic chitosan-based flocculant with a high water Solubility for pulp mill wastewater treatment, Water Res. 43, 5267–5275, 2009.

19. K. Madhumathi, P.T. Sudheesh Kumar, S. Abhilash, V. Sreeja, H. Tamura, K. Manzoor, S.V. Nair, R. Jayakumar, Development of novel chitin/nanosil-Ver composite scaffolds for wound dressing applications, J. Mater. Sci. Mater.Med. 21, 807–813, 2010.

20. R. Jayakumar, M. Prabaharan, R.L. Reis, J.F. Mano, Graft copolymerized chi-Tosan—present status and applications, Carbohydr. Polym. 62, 142–158, 2005.

21. N. Saranya, A. Moorthi, S. Saravanan, M.P. Devi, N. Selvamurugan, Chitosan And its derivatives for gene delivery, Int. J. Biol. Macromol. 48, 234–238, 2011.

22. R. Jayakumar, N. New, S. Tokura, H. Tamura, Sulfated chitin and chitosan as Novel biomaterials, Int. J. Biol. Macromol. 40, 175–181, 2007.

23. A. Khan, R.A. Khan, S. Salmieri, C. Le Tien, B. Riedl, J. Bouchard, G. Chauve, V. Tan, M.R. Kamal, M. Lacroix, Mechanical and barrier properties Of nanocrystalline cellulose reinforced chitosan based nanocomposite films, Carbohydr. Polym. 90, 1601–1608, 2012.

24. M.R. de Moura, F.A. Aouada, R.J. Avena-Bustillos, T.H. McHugh, J.M. Krochta, L.H.C. Mattoso, Improved barrier and mechanical properties of Novel hydroxypropyl methylcellulose edible films with chitosan/tripolyphos-Phate nanoparticles, J. Food Eng. 92, 448–453, 2009.

25. H. Kjellgren, M. Gällstedt, G. Engström, L. Järnström, Barrier and surface Properties of chitosan-coated greaseproof paper, Carbohydr. Polym. 65, 453–460, 2006.

26. M. Gällstedt, M.S. Hedenqvist, Packaging-related mechanical and barrier Properties of pulp–fiber–chitosan sheets, Carbohydr. Polym. 63, 46–53, 2006.

27. T. Bourtoom, M. S. Chinnan, Preparation and properties of rice starch–chi-Tosan blend biodegradable film, LWT – Food Sci. Technol. 41, 1633–1641, 2008.

28. H. Oguzlu, F. Tihminlioglu, preparation and barrier properties of chitosan-Layered silicate Nano composite films, Macromol. Symp. 298, 91–98, 2010.

29. R. Yoksan, S. Chirachanchai, Silver nanoparticle-loaded chitosan–starch Based films: Fabrication and evaluation of tensile, barrier and antimicrobial Properties, Mater. Sci. Eng. C. 30, 891–897, 2010.

30. M. A. Garcia, A. Pinotti, N. E. Zaritzky, Physicochemical, water vapor bar-Rier and mechanical properties of corn starch and chitosan composite films, Starch – Stärke. 58, 453–463, 2006.

31. A. Bhattacharya, B.N. Misra, Grafting: a versatile means to modify polymers: Techniques, factors and applications, Prog. Polym. Sci. 29, 767–814, 2004.

32.Baranwal, A.; Kumar, A.; Priyadharshini, A.; Oggu, G.S.; Bhatnagar, I.; Srivastava, A.; Chandra, P. Chitosan: An undisputed bio-fabrication material for tissue engineering and bio-sensing applications. Int. J. Biol. Macromol. 2018, 110, 110–123.

33. Kumar, S.; Kesharwani, S.S.; Kuppast, B.; Rajput, M.; Ali Bakkari, M.; Tummala, H. Discovery of inulin acetate as a novel immune-active polymer and vaccine adjuvant: Synthesis, material characterization, and biological evaluation as a toll-like receptor-4 agonist. J. Mater. Chem. B 2016, 4, 7950–7960.

34. Razmi, F.A.; Ngadi, N.; Wong, S.; Inuwa, I.M.; Opotu, L.A. Kinetics, thermodynamics, isotherm and Regeneration analysis of chitosan modified pandan adsorbent. J. Clean. Prod. 2019, 231, 98–109.

35. Ren, L.; Xu, J.; Zhang, Y.; Zhou, J.; Chen, D.; Chang, Z. Preparation and characterization of porous Chitosan microspheres and adsorption performance for hexavalent chromium. Int. J. Biol. Macromol. 2019, 135, 898–906.

36. Braz, E.M.A.; Silva, S.C.C.C.; Sousa Brito, C.A.R.; Brito, L.M.; Barreto, H.M.; Carvalho, F.A.A.; Santos, L.S.; Lobo, A.O.; Osajima, J.A.; Sousa, K.S.; et al. Spectroscopic, thermal characterizations and bacteria Inhibition of chemically modified chitosan with phthalic anhydride. Mater. Chem. Phys. 2020, 240, 122053.

37. Wang, J.; Wang, L.; Yu, H.; Zain U.L., A.; Chen, Y.; Chen, Q.; Zhou, W.; Zhang, H.; Chen, X. Recent Progress on synthesis, property and application of modified chitosan: An overview. Int. J. Biol. Macromol. 2016, 88, 333–344.

38. Cai, J.; Dang, Q.; Liu, C.; Fan, B.; Yan, J.; Xu, Y.; Li, J. Preparation and characterization of N-benzoyl-O-Acetyl-chitosan. Int. J. Biol. Macromol. 2015, 77, 52–58.

39. Medeiros Borsagli, F.G.L.; Carvalho, I.C.; Mansur, H.S. Amino acid-grafted and N-acylated chitosan Thiomers: Construction of 3D bio-scaffolds for potential cartilage repair applications. Int. J. Biol. Macromol. 2018, 114, 270–282.

40. Al-Remawi, M. Application of N-hexoyl chitosan derivatives with high degree of substitution in the Preparation of super-disintegrating pharmaceutical matrices. J. Drug Deliv. Sci. Technol. 2015, 29, 31–41.

41. Azmy, E.A.M.; Hashem, H.E.; Mohamed, E.A.; Negm, N.A. Synthesis, characterization, swelling and Antimicrobial efficacies of chemically modified chitosan biopolymer. J. Mol. Liq. 2019, 284, 748–754.

42. Sutirman, Z.A.; Sanagi, M.M.; Abd Karim, J.; Abu Naim, A.; Wan Ibrahim, W.A. New crosslinked-Chitosan graft poly(N-vinyl-2-pyrrolidone) for the removal of Cu(II) ions from aqueous solutions. Int. J. Biol. Macromol. 2018, 107 Pt A, 891–897.

43. Nanda, B.; Manjappa, A.S.; Chuttani, K.; Balasinor, N.H.; Mishra, A.K.; Ramachandra Murthy, R.S. Acylated chitosan anchored paclitaxel loaded liposomes: Pharmacokinetic and biodistribution study in Ehrlich ascites tumor bearing mice. Int. J. Biol. Macromol. 2019, 122, 367–379.

44. Sheik, S.; Sheik, S.; Nagaraja, G.K.; Chandrashekar, K.R. Thermal, Morphological and Antibacterial Properties of Chitosan Grafted Silk Fibre Reinforced PVA Films. Mater. Today Proc. 2018, 5, 21011–21017.

45. Sheik, S.; Sheik, S.; Nairy, R.; Nagaraja, G.K.; Prabhu, A.; Rekha, P.D.; Prashantha, K. Study on the Morphological and biocompatible properties of chitosan grafted silk fibre reinforced PVA films for tissue Engineering applications. Int. J. Biol. Macromol. 2018, 116, 45–53.

46. Woraphatphadung, T.; Sajomsang, W.; Gonil, P.; Saesoo, S.; Opanasopit, P. Synthesis and characterization Of pH-responsive N-naphthyl-N,O-succinyl chitosan micelles for oral meloxicam delivery. Carbohydr. Polym. 2015, 121, 99–106.

47. Bidgoli, H.; Khodadadi, A.A.; Mortazavi, Y. A hydrophobic/oleophilic chitosan-based sorbent: Toward an Effective oil spill remediation technology. J. Environ. Chem. Eng. 2019, 7, 103340.

48. Vasnev, V.A.; Tarasov, A.I.; Markova, G.D.; Vinogradova, S.V.; Garkusha, O.G. Synthesis and properties Of acylated chitin and chitosan derivatives. Carbohydr. Polym. 2006, 64, 184–189.

49. Yang, T.-C.; Chou, C.-C.; Li, C.-F. Antibacterial activity of N-alkylated disaccharide chitosan derivatives. Int. J. Food Microbiol. 2005, 97, 237–245

50. Viswanathan, N.; Meenakshi, S. Enhanced fluoride sorption using La(III) incorporated carboxylated Chitosan beads. J. Colloid Interface Sci. 2008, 322, 375–383.

51. Ercelen, S.; Zhang, X.; Duportail, G.; Grandfils, C.; Desbrieres, J.; Karaeva, S.; Tikhonov, V.; Mely, Y.; Babak, V. Physicochemical properties of low molecular weight alkylated chitosans: A new class of Potential nonviral vectors for gene delivery. Colloids Surf. B 2006, 51, 140–148.

52. Viswanathan, N.; Meenakshi, S. Selective sorption of fluoride using Fe(III) loaded carboxylated chitosan Beads. J. Fluor. Chem. 2008, 129, 503–509.

53. Kurniasih, M.; Cahyati, T.; Dewi, R.S. Carboxymethyl chitosan as an antifungal agent on gauze. Int. J. Biol. Macromol. 2018, 119, 166–171.

54. Zhang, A.; Zhang, Y.; Pan, G.; Xu, J.; Yan, H.; Liu, Y. In situ formation of copper nanoparticles in Carboxylated chitosan layer: Preparation and characterization of surface modified TFC membrane with Protein fouling resistance and long-lasting antibacterial properties. Sep. Purif. Technol. 2017, 176, 164–1

55. Mohammadi, E.; Daraei, H.; Ghanbari, R.; Dehestani Athar, S.; Zandsalimi, Y.; Ziaee, A.; Maleki, A.; Yetilmezsoy, K. Synthesis of carboxylated chitosan modified with ferromagnetic nanoparticles for Adsorptive removal of fluoride, nitrate, and phosphate anions from aqueous solutions. J. Mol. Liq. 2019, 273, 116–124

56..He, G.; Chen, X.; Yin, Y.; Zheng, H.; Xiong, X.; Du, Y. Synthesis, characterization and antibacterial activity Of salicyloyl chitosan. Carbohydr. Polym. 2011, 83, 1274–1278.

57. Li, H.; Zhang, Z.; Bao, X.; Xu, G.; Yao, P. Fatty acid and quaternary ammonium modified chitosan Nanoparticles for insulin delivery. Colloids Surf. B 2018, 170, 136–143.

58. Liu, W.; Qin, Y.; Liu, S.; Xing, R.; Yu, H.; Chen, X.; Li, K.; Li, P. Synthesis, characterization and antifungal Efficacy of chitosan derivatives with triple quaternary ammonium groups. Int. J. Biol. Macromol. 2018, 114, 942–949.

59. Zhou, Y.; Yang, H.; Liu, X.; Mao, J.; Gu, S.; Xu, W. Potential of quaternization-functionalized chitosan Fiber for wound dressing. Int. J. Biol. Macromol. 2013, 52, 327–332.

60. Li, Z.; Chen, Z.; Chen, H.; Chen, K.; Tao, W.; Ouyang, X.; Mei, L.; Zeng, X. Polyphenol-Based Hydrogels: Pyramid Evolution from Crosslinked Structures to Biomedical Applications and the Reverse Design. Bioact. Mater. 2022, 17, 49–70. [CrossRef] [PubMed]

61. Kawakami, S.; Morinaga, M.; Tsukamoto-Sen, S.; Mori, S.; Matsui, Y.; Kawama, T. Constituent Characteristics and Functional Properties of Passion Fruit Seed Extract. Life 2021, 12, 38. [CrossRef]

62. Stiller, A.; Garrison, K.; Gurdyumov, K.; Kenner, J.; Yasmin, F.; Yates, P.; Song, B.-H. From Fighting Critters to Saving Lives: Polyphenols in Plant Defense and Human Health. Int. J. Mol. Sci. 2021, 22, 8995. [CrossRef]

63. Singh, S.; Kaur, I.; Kariyat, R. The Multifunctional Roles of Polyphenols in Plant-Herbivore Interactions. Int. J. Mol. Sci. 2021, 22, 1442. [CrossRef] [PubMed]

64. Quideau, S.; Deffieux, D.; Douat-Casassus, C.; Pouységu, L. Plant Polyphenols: Chemical Properties, Biological Activities, and Synthesis. Angew. Chem. Int. Ed. 2011, 50, 586–621. [CrossRef] [PubMed]

65. Es-safi, I.; Mechchate, H.; Amaghnouje, A.; Jawhari, F.Z.; Al Kamaly, O.M.; Imtara, H.; Grafov, A.; Bari, A.; Bousta, D. An Insight Into the Anxiolytic and Antidepressant-Like Proprieties of Carum carvi L. and Their Association with Its Antioxidant Activity. Life 2021, 11, 207. [CrossRef]

66. Sirše, M. Effect of Dietary Polyphenols on Osteoarthritis—Molecular Mechanisms. Life 2022, 12, 436. [CrossRef]

67. Ko, Y.H.; Jeong, M.; Jang, D.S.; Choi, J.-H. Gomisin L1, a Lignan Isolated from Schisandra Berries, Induces Apoptosis by Regulating NADPH Oxidase in Human Ovarian Cancer Cells. Life 2021, 11, 858. [CrossRef]

68.N. Kerru, L. Gummidi, S. Maddila, K.K. Gangu, S.B. Jonnalagadda, A review on Recent advances in nitrogen-containing molecules and their biological applications, Molecules 25 (8) (2020).

69.Y. Bansal, O. Silakari, The therapeutic journey of benzimidazoles: a review, Bioorg. Med. Chem. 20 (21) (2012) 6208–6236.

70. M. Rashid, A. Husain, R. Mishra, S. Karim, S. Khan, M. Ahmad, N. Al-wabel, Husain, A. Ahmad, S.A. Khan, Design and synthesis of benzimidazoles Containing substituted oxadiazole, thiadiazole and triazolo-thiadiazines as a source Of new anticancer agents, Arab. J. Chem. 12 (8) (2019) 3202–3224.

71.H. Bektas¸, B.B. Sokmen, ¨ S. Aydın, E. Mentes¸e, A. Bektas¸, G. Dilekçi, Design, Synthesis, and characterization of some new benzimidazole derivatives and Biological evaluation, J. Heterocyclic Chem. 57 (5) (2020) 2234–2242.

72. M.F. Hamza, N.A. Hamad, D.M. Hamad, M.S. Khalafalla, A.A.H. Abdel-Rahman, I. F. Zeid, Y. Wei, M.M. Hessien, A. Fouda, W.M. Salem, Synthesis of eco-friendly Biopolymer, alginate-chitosan composite to adsorb the heavy metals, Cd(II) and Pb (II) from contaminated effluents, Materials 14 (9) (2021).

73.A. Gamal, A.G. Ibrahim, E.M. Eliwa, A.H. El-Zomrawy, S.M. El-Bahy, Synthesis and Characterization of a novel benzothiazole functionalized chitosan and its use for Effective adsorption of Cu(II), Int. J. Biol. Macromol. 183 (2021) 1283–1292.

74. B. Singh, I. Boukhris, V.Kumar Pragya, A.N. Yadav, A. Farhat-Khemakhem,Kumar, D. Singh, M. Blibech, H. Chouayekh, O.A. Alghamdi, Contribution of Microbial phytases to the improvement of plant growth and nutrition: a review, Pedosphere 30 (2020) 295–313

75. A.M. Eid, A. Fouda, M.A. Abdel-Rahman, S.S. Salem, A. Elsaied, R. Oelmüller, M. Hijri, A. Bhowmik, A. Elkelish, S.E. Hassan, Harnessing bacterial endophytes for Promotion of plant growth and biotechnological applications: an overview, Plants 10 (5) (2021).

76. M. Safarzadeh, S. Sadeghi, M. Azizi, M. Rastegari-Pouyani, R. Pouriran, M.Haji Molla Hoseini, Chitin and chitosan as tools to combat COVID-19: A triple approach, Int. J. Biol. Macromol. 183 (2021) 235–244.

77. M.R. Vijayakumar, A.H. Sathali, K. Arun, Formulation and Evaluation of Diclofanac Potassium Ethosomes, Madurai Medical College, Madurai, 2010. Doctoral Dissertation.

78.P.G. Green, Iontophoretic delivery of peptide drugs, J. Control. Release 41 (1–2) (1996) 33–48.

79. J. Patel, B. Patel, H. Banwait, K. Parmar, M. Patel, Formulation and evaluation of Topical aceclofenac gel using different gelling agent, Int. J. Drug Dev. Res. 3 (1) (2011) 156–164.

80. D. Sanjay, M. Bhaskar, J.R. Patel, Enhanced percutaneous permeability of acyclovir By dmso from topical gel formulation, Int. J. Pharm. Sci. Drug Res. 1 (1) (2009).

81.A. Gupta, A.K. Mishra, A.K. Singh, V. Gupta, P. Bansal, Formulation and evaluation Of topical gel of diclofenac sodium using different polymers, Drug Invent. Today 2 (5) (2010) 250–253.

82. Mojallal-Tabatabaei Z, Foroumadi P, Toolabi M, Goli F, Moghimi S, Kaboudanian-Ardestani S, Foroumadi A (2019) 2-(Bipiperidin-1-yl)-5-(nitroaryl)-1, 3, 4-thiadiazoles: synthesis, evaluation of in vitro leishmani-Cidal activity, and mechanism of action. Bioorg Med Chem 27:3682–3691

83 . Yan L, Deng M, Chen A, Li Y, Zhang W, Du Z-y, Dong C-z, Meunier B, Chen H (2019) Synthesis of N-pyrimidin [1, 3, 4] oxadiazoles and N-pyrimidin [1, 3, 4]-thiadiazoles from 1, 3, 4-oxadiazol-2-amines and 1, 3, 4-thiadi-Azol-2-amines via Pd-catalyzed heteroarylamination. Tetrahedron Lett 60:1359–1362

84. Muğlu H, Yakan H, Shouaib HA (2020) New 1, 3, 4-thiadiazoles based on Thiophene-2-carboxylic acid: synthesis, characterization, and antimicro-Bial activities. J Mol Struct 1203:127470

85. Muğlu H, Şener N, Emsaed HAM, Özkınalı S, Özkan OE, Gür M (2018) Synthesis and characterization of 1, 3, 4-thiadiazole compounds derived From 4-phenoxybutyric acid for antimicrobial activities. J Mol Struct

86. Jakovljević K, Matić IZ, Stanojković T, Krivokuća A, Marković V, Joksović MD, Mihailović N, Nićiforović M, Joksović L (2017) Synthesis, antioxi-Dant and antiproliferative activities of 1, 3, 4-thiadiazoles derived from Phenolic acids. Bioorg Med Chem Lett 27:3709–3715

87. Zhang J, Wang X, Yang J, Guo L, Wang X, Song B, Dong W, Wang W (2020) Novel diosgenin derivatives containing 1, 3, 4-oxadiazole/thia-Diazole moieties as potential antitumor agents: design, synthesis and Cytotoxic evaluation. Eur J Med Chem 186:111897

88. Quintana C, Klahn AH, Artigas V, Fuentealba M, Biot C, Halloum I, KreMer L, Arancibia R (2015) Cyrhetrenyl and ferrocenyl 1, 3, 4-thiadiazole Derivatives: synthesis, characterization, crystal structures and in vitro Antitubercular activity. Inorg Chem Commun 55:48–50

89. Haider S, Alam MS, Hamid H, Dhulap A, Kumar D (2019) Design, synThesis and biological evaluation of benzoxazolinone-containing 1, 3,4-thiadiazoles as TNF-α inhibitors. Heliyon 5:e01503

90. Luszczki JJ, Karpińska M, Matysiak J, Niewiadomy A (2015) CharacTerization and preliminary anticonvulsant assessment of some 1, 3,4-thiadiazole derivatives. Pharmacol Rep 67:588–592

91. Jakovljević K, Joksović MD, Botta B, Jovanović LS, Avdović E, Marković Z, Mihailović V, Andrić M, Trifunović S, Marković V (2019) Novel 1, 3,4-thiadiazole conjugates derived from protocatechuic acid: synthesis,Antioxidant activity, and computational and electrochemical studies. C R Chimie 22:585–598

92. Sadat-Ebrahimi SE, Mirmohammadi M, Tabatabaei ZM, Arani MA, JafariAshtiani S, Hashemian M, Foroumadi P, Yahya-Meymandi A, MoghimiS, Moshaf MH (2019) Novel 5-(nitrothiophene-2-yl)-1, 3, 4-thiadiazole Derivatives: synthesis and antileishmanial activity against promastigote Stage of leishmania major. Iran J Pharm Res 18:1816

93. Chen J, Yi C, Wang S, Wu S, Li S, Hu D, Song B (2019) Novel amide Derivatives containing 1, 3, 4-thiadiazole moiety: design, synthesis,Nematocidal and antibacterial activities. Bioorg Med Chem Lett 29:1203–1210

94. Er M, Özer A, Direkel Ş, Karakurt T, Tahtaci H (2019) Novel substituted Benzothiazole and Imidazo [2, 1-b][1, 3, 4] thiadiazole derivatives: Synthesis, characterization, molecular docking study, and investigation Of their in vitro antileishmanial and antibacterial activities. J Mol Struct 1194:284–296

95. Fascio ML, Sepúlveda CS, Damonte EB, D'Accorso NB (2019) Synthesis And antiviral activity of some imidazo [1, 2-b][1, 3, 4] thiadiazole carboHydrate derivatives. Carbohydr Res 480:61–66

96. Chawla G, Kumar U, Bawa S, Kumar J (2012) Syntheses and evaluaTion of anti-infammatory, analgesic and ulcerogenic activities of 1, 3,4-oxadiazole and 1, 2, 4-triazolo [3, 4-b]-1, 3, 4-thiadiazole derivatives. J Enzyme Inhib Med Chem 27:658–665

97. Kaur H, Kumar S, Vishwakarma P, Sharma M, Saxena KK, Kumar A (2010) Synthesis and antipsychotic and anticonvulsant activity of some neSubstituted oxa/thiadiazolylazetidinonyl/thiazolidinonylcarbazoles. Eur J Med Chem 45:2777–2783

98. Oruç EE, Rollas S, Kandemirli F, Shvets N, Dimoglo AS (2004) 1, 3, 4-thiadiazole derivatives. Synthesis, structure elucidation, and struc-Ture−antituberculosis activity relationship investigation. J Med Chem 47:6760–6767

99. Yusuf M, Khan RA, Ahmed B (2008) Syntheses and anti-depressant activityOf 5-amino-1, 3, 4-thiadiazole-2-thiol imines and thiobenzyl derivatives. Bioorg Med Chem 16:8029–8034

100. Turner S, Myers M, Gadie B, Nelson AJ, Pape R, Saville JF, Doxey JC, Ber-Ridge TL (1988) Antihypertensive thiadiazoles. 1. Synthesis of some 2-aryl-5-hydrazino-1, 3, 4-thiadiazoles with vasodilator activity. J Med Chem 31:902–906

101. H. Mirhosseini, B.T. Amid, A review study on chemical composition and Molecular structure of newly plant gum exudates and seed gums, Food Res. Int. 46, 387–398, 2012.

102. P.J. Manna, T. Mitra, N. Pramanik, V. Kavitha, A. Gnanamani, P.P. Kundu, Potential use of curcumin loaded carboxymethylated guar gum grafted gel-Atin film for biomedical applications, Int. J. Biol. Macromol. 75, 437–446, 2015.

103. Bosio, V.E., Basu, S., Abdullha, F., Villalba Chacon, M.E., Guida, J.A., Mukherjee, A., Castro, G.R., 2014. Encapsulation of Congo Red in carboxymethyl guar gum–alginate gel microspheres, Reactive & Functional Polymers 82, 103–110.

104. Shirakawa, , H. Louis E. J. MacDiarmid, A.G. C.K. Chiang and Heeger, A.J. Chem, J.C.S., Comm. Physical Rev. 578, (1977).

105. Heeger, A.J.; Kirelson, S.; Schrieffr, J.R.,and Su, W.P.. Solitons in Conducting Polymers.Rev. Mod. Phys.,60,781p.(1988)

106. Mishra, A.K., Journal of atomic, condensate &nano physics, 5, No.2, pp 159-193 (2018).

107. Barford. W, International Series of Monographs on Physics, 129. Electronic and Optical Properties of Conjugated Polymers, Oxford University Press Inc., New York,2005, p1.

108. Carraher, C.E.., Dekkerr, M., Semoury/ Carraher,S polymer chemistry, 4th edition, New York (1996).

109. Khattab,A.F. and Abbas,M.F., International Journal of Enhanced Research in Science,Technology & Engineering, 4(8),PP 1-10. (2015).

110. Chen H. and Cao Y., Acc. Chem. Res., 42.1709 (2009).

111. Ayoob, H. A., Khattab,A.F. and Al Taan, L. M., Journal of Education and Science, 29, No.4, pp 140- 153 (2020).

112. Al Assawi, A. M., and Yaseen, H. K., Journal of Chemical and Pharmaceutical Research,8(8), 241- 247 (2016).

113. Yang Wang and Tsuyoshi Michinobu, Journal of Materials Chemistry C,4,6200 (2016).

114.-Majeed, A.H. and Al- Tikrity, E.T.B, Polymer and Polymer Composites, pp1-12, (2020).

115..Ayoob, H.A., Al Taan, L. and Khattab,A.F., Rafidain J. of science,29(4), pp66-76 (2020).H.A., Al Taan,

116. F. Jonasa, J. T. Morrison b, a) Bayer AG, ZF, Geb. R79 Rhein Uferstrasse, D47812 Krefeld, Germany- b) Bayer Corp., 100 Bayer Road, Pittsburgh, PA 152059741, USA." Polyethylenedioxythiophene (PEDT): 'Conductive Coatings Technical Applications and Properties" Synthetic Metals, 85, 1397-1398 (1997).

117.D. Ateh, H. Navsaria, P. Vadgama, "Polypyrrole-based conducting polymers and interactions with biological tissues", J. R. Soc. Interface 3, 741e752, (2006)

118.M.G. Kanatzidis Chem. Eng. News 3, 36,(1990).2014

119. Roth, S. "One-Dimensional Metals" Weinheim VCH, (1995).

120. W. R. Salaneck, I. Lundström, and B. Ranby," Nobel Symposium in Chemistry: Conjugated Polymers and Related Materials": The Interconnection of Chemical and Electronic Structure, Ed's (Oxford Sci., Oxford, (1993).

121.J.H. Burroughes, D.D.C. Bradley, A.R. Brown, R.N. Marks, K. Mackay, R.H. Friend, P.L. Burns and A.B. Holmes Nature 347, 539,(1990).

122.R.H. Friend, R.W. Gymer, A.B. Holmes, J.H. Burroughes, R.N. Marks, C. Taliani, D.D.C. Bradley, D.A. Dos Santos, J.L. Bredas, M. Lögdlund and W.R. Salaneck Nature 397,121, (1999).

123.http://nobelprize.org/nobel_prizes/chemistry/laureates/2000/index.html.